THE ORIGINS AND AFFINITIES OF THE ORTHOPTERA OF THE CHANNEL ISLANDS AND ADJACENT MAINLAND CALIFORNIA
PART I
THE GENUS *CNEMOTETTIX*

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ABSTRACT. — Crickets of the genus *Cnemotettix* occur only in central California and all of the Channel Islands except the smallest, Santa Barbara. Prior to this study a single species was known for the genus but our investigations show that at least five species are present in the genus, one only known from the mainland, one shared with the mainland and Santa Catalina, and three found only on the islands. These insects are among the only Orthoptera with the ability to spin silk which they produce from their maxillary glands. It is utilized in reinforcement of their burrows in sandy areas. Our analysis suggests radiation and speciation on the Channel Islands. This situation is in contrast to the convincing evidence presented by the botanists which indicates that most of the Channel Island floristic endemics are relicts of extensive past mainland distributions.

INTRODUCTION

This is the first in a series of publications concerning the origins and affinities of the Orthoptera of the Channel Islands and adjacent coastal California. The present study concerns a single genus, *Cnemotettix* Caudell, known from five species, only two of which occur on the California mainland. One of these is shared with Santa Catalina Island; the other is known solely from continental California. The remaining species are all endemic to the Channel Islands.

The crickets of the genus *Cnemotettix* are among the most poorly known of all California Orthoptera. To this point nothing has been published on their biology or the fact that they are able to produce silk. This trait, though not unique among Orthoptera, is known from only a handful of other species. *Cnemotettix* is the only temperate North American representative of the stenopelmatid subfamily Henicinae. Most species of henicines in the New World occur in tropical or subtropical regions. In the southern hemisphere these insects occur in arid regions as well as the tropics. The closest relative of *Cnemotettix* is the tropical Mexican genus *Glaphyrosoma* Brunner. This latter genus contains three poorly known species. Nothing has been written concerning the biology or ecology of any of the species.

Though not technically considered camel crickets, a term usually meant for representatives of the family Rhaphidophoridae, for lack of a better name, we are going to refer to these insects as silk-spinning sand crickets. They have the general appearance of camel crickets, although they are not humpbacked. They are wingless and live primarily on the ground, and the average entomologist would probably refer to them as such.

THE CALIFORNIA ISLANDS

The California Islands off the Coast of southern California have been variously referred to as the Channel Islands, California Offshore Islands and Baja California Islands. Collectively they are called the California Islands. In the broad sense they con-

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sist of sixteen major islands or groups of islands spread over five hundred miles between Point Conception, California and Punta Eugenia, Baja California. Our studies, at the present, deal only with the most northern group of these islands, the islands referred to as the Channel Islands. These islands in relation to the mainland are illustrated in figure 1. The Channel Islands can further be subdivided into a northern and a southern group. The Los Coronados Islands are not considered in this report. Below we list the islands according to size, and include distance from the mainland and distance to the closest island.

The Channel Islands are good examples of a fringing archipelago; none should be considered as oceanic. A great many studies have appeared concerning the geology and flora and fauna of these islands, and they are considered relatively well known biologically. The insects as a whole are among the least known of any of the organisms. No concerted effort has been made to follow through a comprehensive study of one group for all of the islands. This may be due in large measure to the rather involved logistical problems one encounters getting to all the islands during a single season. Some of the outstanding publications concerning the Channel Islands are as follows: botany, Dunkle (1950), Eastwood (1929), Axelrod (1967), Lathrop and Thorne (1968), Raven (1963), Raven and Thompson (1966), Thorne (1967, 1969B) and Philbrick (1972); geology, Weaver and Doerner (1967), Valentine and Lipps (1967), Savage and Downs (1959). Numerous publications involving the animals of the Channel Islands have appeared and reference to many of these can be found in the Proceedings of the Symposium on the Channel Islands edited by Philbrick (1967). Also see Power (1972) for a discussion of the Avian bionomics. An attempt to survey the insects was made by the Los Angeles County Museum in the late 1930's and early 1940's. The results of part of the survey have appeared in the Bulletin of the Southern California Academy of Sciences over a period of years. Most of these papers are taxonomic in nature and have few statements relative to the evolution or origin of the insects concerned. The most recent investigation involving a group of insects from the Channel Islands is that of Miller (1971), which details the origins and affinities of the mealy-bugs of Santa Cruz Island. A useful summary of most of the known biological and geological information is provided by Thorne (1969A).

The most important element in the interpretation of the distribution phenomena of the Channel Islands biota is the geological history of the region. This is particularly true of *Cnemotettix,* as all species are flightless and must thus depend upon land connections or rafting to account for their presence on the islands. Unfortunately, neither the phylogenetic relationships of the various *Cnemotettix* species nor the geological history of this area are known in fine enough detail to distinguish absolutely between possible cases of rafting versus land connections. Nevertheless, the *major* geological trends are well enough known to form a picture worthwhile discussing.

The four northern Channel Islands are an extension of the Santa Monica Mountains. The islands have had an active history of emergence and submergence since their first appearance which may have been in Cretaceous times. Of biological importance, though, in interpreting extant species distributions, is the fact that the last submergence, which occurred in the Pleistocene, was probably of sufficient magnitude to completely submerge the

Island	Area (sq. mi.)	Distance from mainland (mi.)	Distance from closest island distance (mi.)	Island
Santa Cruz	96	19	5, 6	Anacapa, Santa Rosa
Santa Rosa	84	27	3	San Miguel
Santa Catalina	75	20	21	San Clemente
San Clemente	56	49	21	Santa Catalina
San Nicolas	22	61	28	Santa Barbara
San Miguel	14	26	3	Santa Rosa
Anacapa (3 islands)	1.1	13	5	Santa Cruz
Santa Barbara	1.0	38	24	Santa Catalina

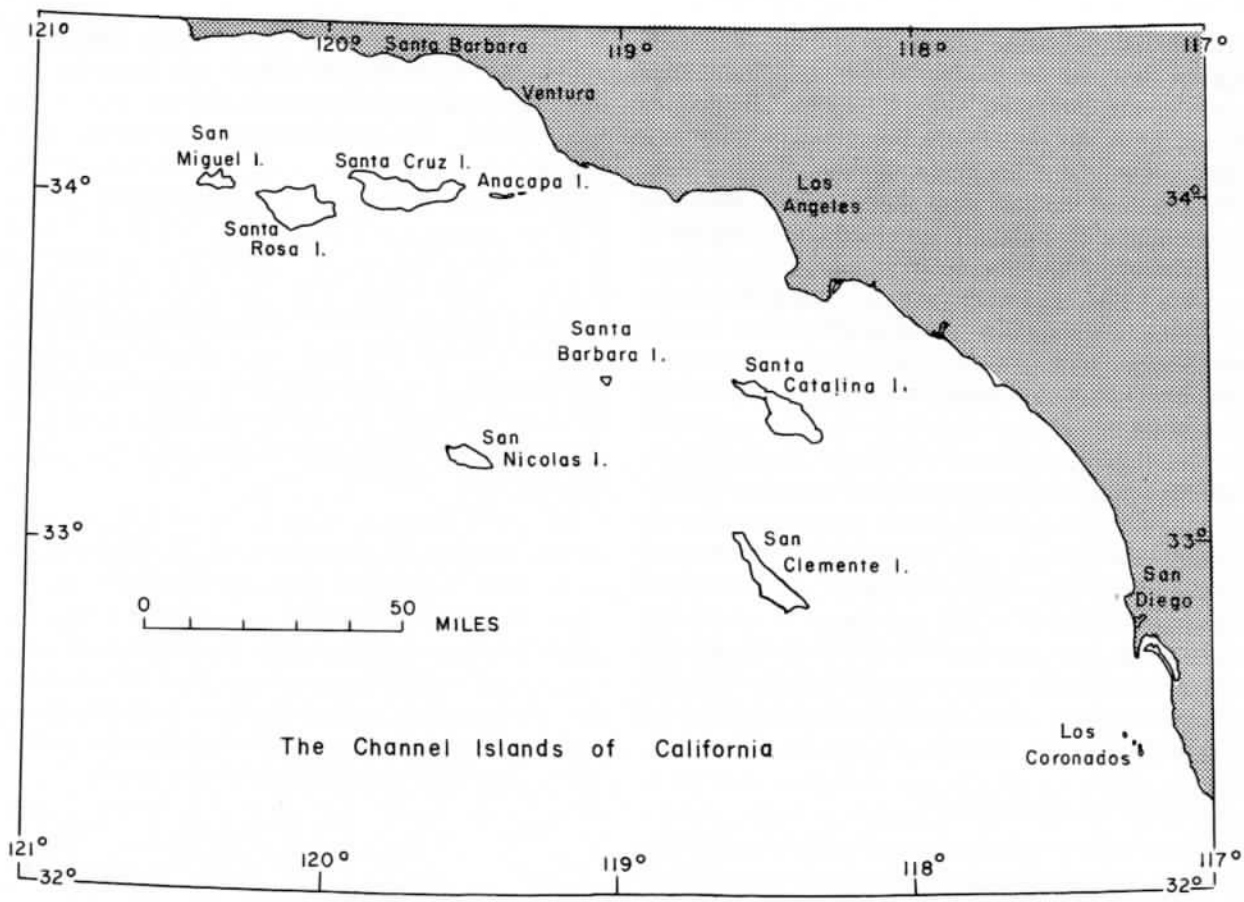

FIGURE 1. — The Channel Islands of California.

islands and eliminate the entire terrestrial biota. Subsequently, with the reconnection of the northern island group to the mainland during the Illinoian glaciation period (around 400,000 years ago), plants and animals again had the opportunity for land transport to these islands.

Eustatically rising sea levels then, once again, isolated the northern islands from the mainland and from each other, but an interisland connection was probably reformed sometime between 100,000 and 18,000 years ago when sea level once again fell. Thus, the four northern islands apparently derived a majority of the present biota overland beginning some 400,000 years ago. These species were then isolated on each island for some 300,000 years, at which time they had the opportunity for interisland mixing.

The geological origin and subsequent history of the southern Channel Islands is quite different from that of the northern ones. All evidence points to the complete terrestrial biota of these islands arriving over water. San Nicolas probably was connected to Santa Rosa in the Pleistocene but later submergence obliterated all living remnants of this association. Santa Barbara was completely underwater during late Pleistocene as were most of San Clemente and Santa Catalina. None of these islands has been connected to the mainland or to other islands since their submergence in late Pleistocene.

In discussing present species distribution patterns in light of the above geological information, a pattern emerges that supports colonization of the islands both through land connection and over-water rafting. But as previously stated, one method of transport cannot always be eliminated, thus leaving the other method as definitive.

The four northern islands, with their *similar* geological past, also show similar distribution patterns of *Cnemotettix* species: *C. caudulus* is confined to the two western islands; *C. spinulus* is confined to the two eastern islands. *C. spinulus* also probably rafted to San Nicolas long enough ago so that now it is apparently a different subspecies than that found on Anacapa and Santa Cruz.

The present diverse species composition of the southern Channel Islands reflects their *isolated, diverse* geological history. San Clemente and San Nicolas each harbor endemic species, in addition to San Nicolas' *C. spinulus*. Catalina has an apparent mainland rafter in *C. miniatus;* and Santa Barbara has no *Cnemotettix* species, thus reflecting difficulty of rafting to such a small island, its apparent absence of any land connections, and possibly the enormous vegetational disturbance caused by the introduced rabbit (Philbrick, 1972).

Until we can collect additional evidence, speculation as to whether or not the three island endemics evolved *in situ* or are relicts of former mainland distributions, is premature.

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San Miguel Island: Robert and Marty DeLong; National Park Service, Steven Leatherwood.

Santa Catalina Island: Catalina Rock and Ranch Company, Douglas Propst, Superintendent of Ranches.

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San Nicolas Island: United States Navy, Pacific Missile Range, Mr. Pomatti.

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Material used in this study has been borrowed from various institutions. Specimens without ownership designations are in the Academy of Natural Sciences; otherwise it can be identified as follows: Academy of Natural Sciences of Philadelphia (ANSP), California Academy of Sciences (CAS), Los Angeles County Museum (LACM), University of Michigan, Museum of Zoology (UMMZ), United States National Museum of Natural History (USNM).

METHODS

Tables. — Undescribed species, or species in which one sex is poorly known, cannot be adequately treated using a key. A detailed, open-ended table can account for new species and enable the user to identify specimens. In this paper, keys are not used, but comparative data are presented in tabular form.

Measurements. — All measurements were made with either an ocular micrometer or vernier calipers. Measurements were made in the following ways:

Length of body — from anterior margin of fastigium to the distal edge of the tenth tergite. This is the most variable measurement because of the

telescoping effect of the abdomen of dry mounted or stuffed specimens.

Length of pronotum — measured along the median.

Breadth of pronotum — measured at the most ventral portion, border to border.

Length of hind femur — measured along ventral portion from lobe of inserting angle to apex.

Length of ovipositor — from base along a line to apex.

Subgenital plates of both male and female — maximum possible measurement.

Preservation. — Some mention of preservation techniques is necessary because of the great difference in value noted between dried specimens and those which have been preserved in fixative. Specimens preserved in fixative, as described by Williams (1968), are far superior in that the soft portions, such as the genitalia, retain their original shape. In dry, pinned specimens these soft parts are often destroyed by decomposition or are hopelessly distorted.

Paratypes. — Unless otherwise indicated, all adult specimens of new species described herein are to be considered as paratypes.

TAXONOMIC HISTORY

Caudell (1916) in his generic revision of the rhaphidophorid insects of America proposed the genus *Cnemotettix* to include one species, *pulvillifer,* which he recorded from San Clemente Island some 49 miles off of the coast of southern California. At the time he indicated that the presence of pulvilli in both *Gammarotettix* and *Cnemotettix* might show relationship to the subfamily Stenopelmatinae. Subsequently (Caudell, 1928), removed *Cnemotettix* from the Rhaphidophorinae to the Stenopelmatinae on the basis of the presence of the "inserting angle" on the outer side of the base of the hind femur. He must have had some reluctance making this change since he noted at the time that ". . . this is not a constant character of the Stenopelmatinae, as it is not present in the genus *Stenopelmatus* or *Cyphoderris,* comprising two of the three Nearctic genera of the Stenopelmatinae." Karny (1929), in his extensive discussion on the geographical distribution of Pacific gryllacridids, placed *Cnemotettix* in the Henicinae, noting its lack of a femoral tympanum, but also pointing out that this character is also absent in the genera of the African group Mimnermi. Hubbell (1936), in his key to subfamilies, left *Cnemotettix* in the Henicinae; and Karny, a year later (1937), in his review of the entire family in the Genera Insectorum, retained this opinion. Detailed examination of additional species by us, in all of the genera, indicates that the genera contained in the Henicinae constitute a cohesive group. A more convenient arrangement of the genera can be made by dividing the Henicinae into three tribes.

There are only seven genera of Henicinae known from the New World. These include: *Anabropsis* Rehn, *Cnemotettix* Caudell, *Mayacris* Cockerell, *Glaphyrosoma* Brunner von Wattenwyl, *Lutosa* Walker, *Licodia* Walker, and *Apotetamenus* Brunner von Wattenwyl. The species in these genera all share the following characters: laterally compressed tarsi with the metatarsus divided ventrally into two distinct pulvilli and the fore tibia armed with at least one and often two spines (single exception; the Glaphyrosomini). In addition, most genera possess some form of auditory tympanum on the fore tibia. The three tribes proposed below are all represented in the New World tropics. Table 1 lists several primary characters — those considered to be less variable and less subject to adaptive modification — shared among several genera of New World Henicinae. The nominate genus, *Henicus* Gray, is included for comparison.

Henicini, Rentz and Weissman new tribe

This tribe is characterized by the presence of at least one and frequently two spines on the dorsal surface of the fore tibia. Sexual dimorphism consisting of allomorphic asymmetrical megacephaly on the part of the male is also common among members of this group. New World representatives include: *Licodia, Lutosa, Apotetamenus,* and *Mayacris;* in the Old World the subfamily is abundantly represented. *Henicus* Gray *Platysiagon* Brunner, and *Faku* Peringuey are typical examples. In each of the genera studied above, the stridulatory apparatus consists of a single complete row of pegs on the inner surface of the hind femur, often with a few accessory pegs at either end. On either side of the row of pegs are many striae arranged in a wavy pattern. The side of the abdominal tergites may possess several prominent spine-like pegs or additional striae. This stridulatory apparatus is never remotely similar

TABLE 1. — Distribution of principal characters among New World genera of the Henicinae. *Henicus*, the type genus, known from South Africa, is included for comparison.

	Henicus	Licodia	Lutosa	Apotetamenus	Glaphy.	Cnemo.	Anabropsis
1. Auditory organ	+	+,−	+,−	+	+	−	+
2. Spines on dorsal surface of fore tibia, exclusive of apical spurs	+	+	+	+	−	−	+
3. Stridulatory pegs	+	+,−	−	+ (?)	+	+	−
4. Styles on male subgenital plate	+	+(sub-apical)	+	−	+	+	+
5. Maxillary palpi long (+) short (−)	−	+	−	−	+	+	−
6. Megacephalic sexual dimorphism	+	+	−	−	−	−	−
7. Development of male paraprocts	−	−	+	−	+	+	
8. Prosternal spines	+	+	+	+	−	−	+

to what is seen in *Cnemotettix* (figs. 32, 43). Apterous, brachypterous and fully alate species are known. Rehn (1930) reviewed and described new species of *Licodia* and *Lutosa.*

ANABROPSINI, RENTZ AND WEISSMAN NEW TRIBE

This tribe contains a single genus, *Anabropsis* Rehn 1901, which is composed of species in both the Old and New World tropics. It is distinguished from all other representatives of the Henicinae in possessing a single, distinct longitudinal keel on the external pagina of the hind femur. The fore tibia may or may not bear an auditory tympanum, depending on the species, but this structure is never found only on one side of the tibia. There is no femoro-abdominal stridulatory apparatus in this subfamily. However, females of *Anabropsis costaricensis* Rehn bear several bristle-like setae on the base of the first abdominal tergite. There is no modification of the internal surface of the hind femur. Apterous as well as fully alate species are known.

GLAPHYROSOMINI, RENTZ AND WEISSMAN NEW TRIBE

This tribe is proposed to include two genera — *Glaphyrosoma* Brunner 1888 and *Cnemotettix* Caudell 1916. It is characterized by complete apterism of both sexes; smooth fastigium of vertex; absence of armature on the dorsal surface of the fore tibia; extraordinarily long maxillary palpi associated with silk-production (not yet known in *Glaphyrosoma* but maxillary palpi similarly enlarged); and stridulatory apparatus (figs. 32, 43, 44), present in both sexes, consisting of diagonal rows of pegs on the inner face of the hind femur and two sets of pegs on the opposing first two abdominal tergites. There are several sexual characters for males: a pair of teeth on the dorsal surface of the tenth abdominal tergite; development of the paraprocts; and styles on the subgenital plate. Females possess either elongate or abbreviate ovipositors, without any armature; and the subgenital plate is triangulate, without a median carina.

Both genera are fossorial with the only biological information on *Glaphyrosoma* being that in the field notes of H. R. Roberts based on a collection made from five miles east of Córdoba, Vera Cruz, Mexico, 29 August 1936: "Turned over old banana trunks and found a number of *Glaphyrosoma* in little cavities in the ground." Whether silk lined the cavities was not determined.

THE FAMILIAL PLACEMENT OF *CNEMOTETTIX* AS INDICATED BY THE STRUCTURE OF THE FOREGUT

Judd (1948) published a detailed treatise on the morphology of the proventriculus of orthopteroid insects. He demonstrated its value in higher classification and, with a few subsequent modifications, showed that the gut structure can be a useful tool in

discovering relationships often masked by derived external characters. He included in the Henicinae of the Stenopelmatidae *Hemideina megacephala* Buller and *Cratomelus* species. These species are now considered as representatives of the subfamily Deinacridinae. In effect, he had no representatives of the species considered as typical of the Henicinae in the present sense.

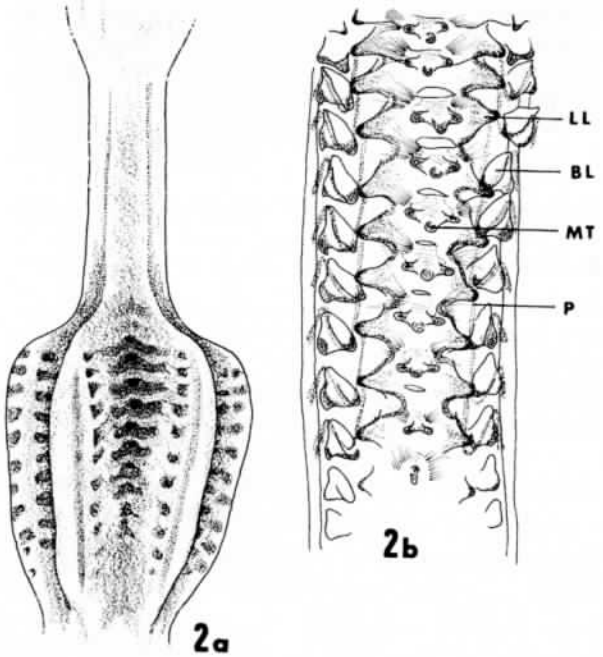
The proventricular structure of ensiferous Orthoptera presents a complex picture. The foregut consists of a globular body (in *Cnemotettix* this aspect is further exaggerated probably owing to the retentive aspect of the gut contents discussed elsewhere) lying between a pair of bulbous gastric caeca. A tubular neck joins the body to the foregut, the internal structure of which consists of six longitudinal folds which bear complex appendages in the globular part. Each appendage is flanked by a hooked lobe and a partition separates each longitudinal fold. The grylloids present even a more complex structure.

STRUCTURE OF THE FOREGUT OF *CNEMOTETTIX*

The proventriculus (fig. 2A) is 2 mm long. In the globular portion, the appendages in the longitudinal row are eleven in number; the anterior appendages are considerably smaller than the others. The structure of the median tooth (fig. 2B MT, 3A, 3B) is tripartite — in this respect different from any other species yet described. The median tooth of most other species of ensiferous orthopteroids discussed by Judd possessed a single median projection, while that of *Hemideina* was bipartite. In the rhaphidophorid *Ceuthophilus maculatus* Harris the median tooth is merely a tuft of hairs with a pair of lateral lobes. In *Cnemotettix pulvillifer* Caudell there are many fine hairs emanating from the base of the median tooth. The anterior barbated lobes are eleven in number, roughly of triangular shape, the median two or three bearing a sharp apical tooth projecting posteriorly. The partitions are broad medially and tapered at each end, especially posteriorly. The lateral lobes are short, blunt projections without any ornamentation.

The sclerotized portion of the gut of *Cnemotettix* species is unlike that of any of the Tettigoniioidea studied by Judd.

Cnemotettix crickets show more in common, regarding the structure of the foregut, with the stenopelmatids than the rhaphidophorids, since the appendages are highly sclerotized and are not merely assemblages of hairs. In this respect, they, like the stenopelmatids, resemble the Tettigoniidae, e.g. *Atlanticus,* more than the Rhaphidophoridae. We therefore conclude that *Cnemotettix* and the other henicines belong in the Stenopelmatidae, not the

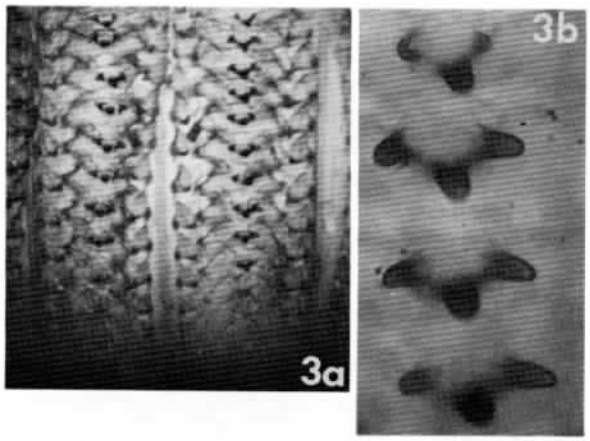


FIGURES 2A, 2B. — Structure of foregut in *Cnemotettix pulvillifer*. 2A, external morphology; 2B, internal morphology. LL, lateral lobe, BL, barbated lobe, MT, median tooth, P, partition. Magnification 2A, 50×; 2B, 100×.

Gryllacrididae or Rhaphidophoridae. In this respect Caudell (1928) was correct, although he arrived at this conclusion using other characters.

EVOLUTION AND BIONOMICS

The silk-spinning sand crickets present an interesting distributional picture to the evolutionary biologist (compare figs. 19, 25, 35, 50, 62). In view of the recent nature of the fauna of the Channel Islands, the question arises as to whether such species as those of *Cnemotettix* are relicts or autochthons. There is little evidence in support of either hypothesis. We have no fossils and an incomplete knowledge of which morphological structures are derived and which are primitive. The fact that we have found



FIGURES 3A, 3B. — Internal morphology of foregut. Note tripartite median tooth and lateral lobes. 3B, tripartite median tooth. Both figures highly magnified.

Cnemotettix species (such as *C. spinulus*) in a number of ecologically different habitats on the Channel Islands indicates that at least some radiation is occurring there. However, we can be certain that the same is not true in parts of the range of *Cnemoetttix* on the mainland. Indeed, the sole dune record from the Morro Bay area does demonstrate that *C. bifasciatus* is capable of living in sand dunes in that portion of its range.

If advantages exist for radiation into the sand dune environment, we would expect to find *Cnemotettix* crickets in similar mainland habitats. The dunes of Pt. Conception and the beaches of the coast adjacent to the Channel Islands would be the logical place to look for the crickets. However, none were found. These latter habitats are densely populated by "sand treader" crickets of the genus *Rhachocnemis* which appear to be much better adapted for such an existence. They bear enlarged hind legs with spatulate, trowel-like spines for digging. Silk-spinning sand crickets possess neither of these characters and, in the laboratory, they are slow to dig into the sand when exposed. *Rhachocnemis* crickets immediately dig back into the sand when uncovered. The absence of *Cnemotettix* species from the adjacent mainland coast may reflect direct competition with other crickets, such as *Rhachocnemis;* predation from an animal not present in sufficient numbers on the islands to be a factor; presence of an arthropod predator or parasite absent from the islands which is able to locate individuals while they are in their burrows; general beach disturbance from human activity; and perhaps a difference in the composition or particle size of the sand along the coast. Some of these factors may have also prevented *Cnemotettix* crickets from radiating onto the dune areas on Santa Catalina and Santa Cruz Islands, although the dunes on these islands are not as extensive as those on San Clemente, San Nicolas, San Miguel, and Santa Rosa Islands.

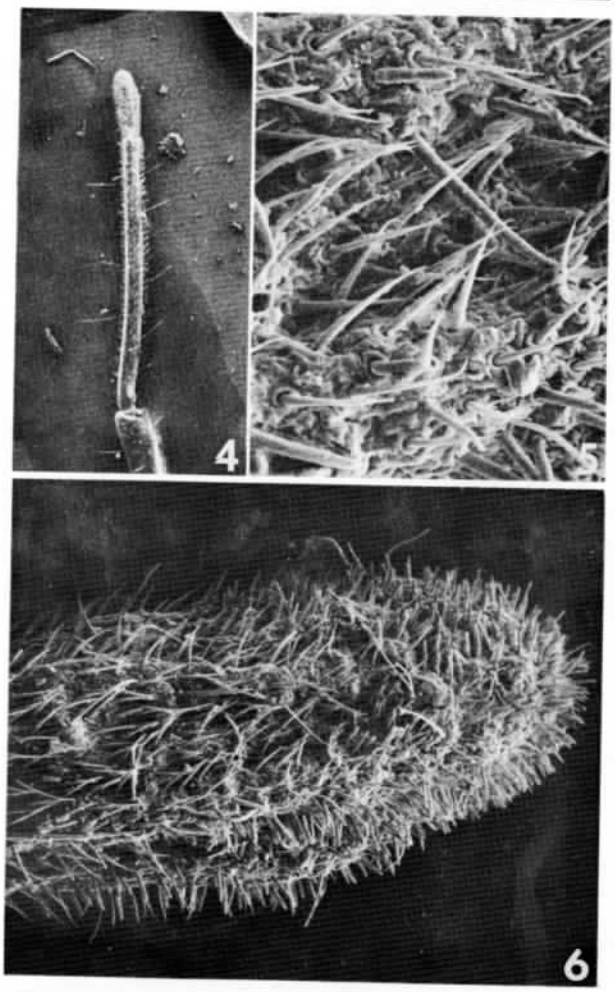
TABLE 2. — Ecological distribution of *Cnemotettix* species.

Species	Habitat
Cnemotettix bifasciatus (scattered locations, but representative of range)	
Monterey Co. 1.5 Miles N. of Carmel	Pine, Oak-grassland 700′
San Luis Obispo Co. Morro Bay Dunes (1 individual)	sand dunes
Santa Barbara Co. 5 Miles E. of Gaviota	?
Ventura Co. Santa Monica Mts.	Chaparral 1800′
Los Angeles Co. Tanbark Flats — San Gabriel Mts.	?
Riverside Co. Idyllwild — San Jacinto Mts.	Pine-fir forest
C. caudulus	
Santa Rosa Island	fossil sand dunes 200′ 1 individual in chaparral 1300′
San Miguel Island	sand dunes 300-700′ (fossilized and soft sand)
C. miniatus	
Tijuana Hills	?
Catalina Islands	chaparral-oak 600′
San Nicolas Island	coastal scrub 400′
C. pulvillifer	
San Clemente Island	sand dunes 100′, 1 individual in coastal scrub 200′
C. spinulus	
San Nicolas Island	sand dunes 575′
Anacapa Island (on all three islands) } may be different subspecies than San Nicolas Is.	coastal scrub 5 — 200′
Santa Cruz Island	chaparral, *Eucalyptus*-grassland 250′

Table 2 summarizes what is known about the bionomics of species of *Cnemotettix*. One can quickly observe that chaparral habitats are prime location from which mainland crickets have been taken. We have spent considerable time collecting on the beaches of southern California, especially on Pt. Conception and on the coast adjacent to the Channel

Islands and we are convinced that *Cnemotettix* does not occur there. We have found it (*C. bifasciatus*) in the Santa Monica Mountains but in the chaparral community several miles from sand dunes.

Silk-spinning is accomplished through secretions of the maxillary glands. Several grains of sand are taken into the mandibles and meticulously rotated. The maxillae and elongated maxillary palpi are well adapted for holding and steadying the sand grains (figs. 4, 5, 6) and the latter are used in rotating them. Once a small packet of sand grains has been sewn together, the cricket fits the packet either on the ceiling or wall of its burrow and sews it into place.

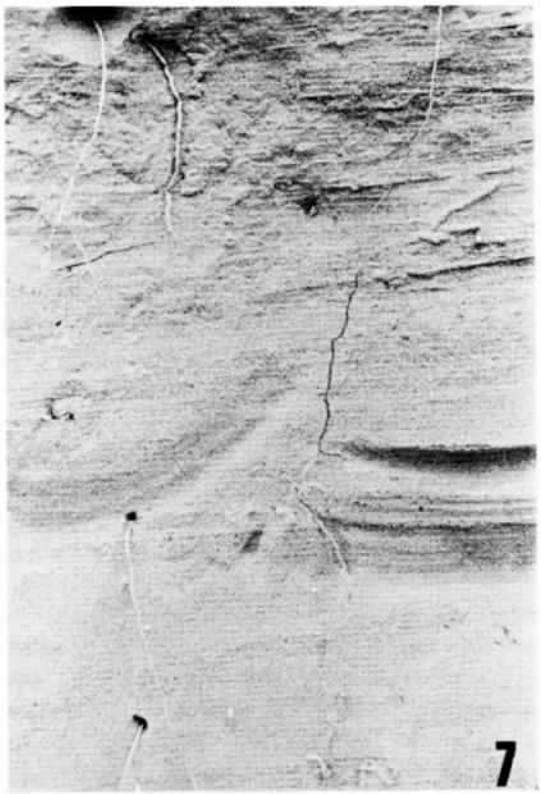


FIGURES 4, 5, 6. — Scanning electron microscopy of maxillary palpus of *Cnemotettix pulvillifer*, 4, palpus at 30×; 5, apex at 1000×; 6, apex at 300×.

As observed in the laboratory, the total construction of a *Cnemotettix* burrow may take many days. The burrows are lined with silk as the hole is dug. On the islands of Santa Rosa and San Miguel, in areas of hard fossilized sand, we are not sure if *Cnemotettix* actually digs its own holes or utilizes holes previously dug by other organisms. Such holes may be constructed by wasps, bees, spiders, or beetles and later abandoned. In addition exposed plant roots (figs. 7, 8), especially of *Ambrosia* (= *Franseria*) *chamissonis* whipped around by the wind, can widen existing root channels considerably. As the roots of a dead plant decay, they leave a deep tunnel which can extend into the sand bank for 10 to 30 cm.

On the islands of San Clemente, San Nicolas and San Miguel, (figs. 9, 10) where we know that the crickets dig their own holes in the soft sand, ever present oceanic winds and the simple passage of the cricket itself through the tunnel could suffice to bring sand caving in around the animals. Holes of *Rhachocnemis* on the mainland, which we excavated during the day, show that this is what happens to unlined burrows. *Cnemotettix* crickets are sometimes found under rocks on the islands, but there is no evidence of spun silk — such areas are not in need of stabilization. These same individuals, when transferred to the laboratory, will spin silk when in association with sand or loose leaves. Mainland individuals from the chaparral, when given either loose leaves or sand, will construct the appropriate sort of shelter associated with that medium.

Silk-spinning sand crickets spend much more time underground than do other sand crickets such as *Rhachocnemis* or *Ammobaenetes* species. Individuals of these genera spend the daylight hours beneath the ground and emerge every night (weather permitting) to forage and perhaps mate on the surface of the dunes. All of these crickets either construct new burrows as daylight approaches or use the nearest empty hole. They do not attempt to relocate the burrows of the previous night. In contrast, some *Cnemotettix* crickets observed in the laboratory remain alive and alert within their sand burrows for weeks at a time with little activity day or night. These same crickets, when placed in cages with loose leaves, show activity every night. This behavioral flexibility (depending upon substrate composition) occurs with all species from all localities.



Fecal pellets of these crickets are unusually large for this group — they are between one-quarter and one-fifth the body length. This might reflect the fact that although the individuals seldom feed, digestion is very complete and efficient, with material being retained in the digestive tract for long periods.

Laboratory observations show that maturation in *Cnemotettix* may take more than one year. Several weeks or months may pass between molts. In the field, all of the life history stages can usually be found together, thus indicating, we believe, both slow development and continuous generations. There is no egg diapause and first instars are capable of silk production (see discussion under *C. spinulus*). Thus, the advantages of a silk-lined burrow (spiders in the same dunes also have silk-lined burrows) to a slow developing organism living in a structurally unstable area is experimentally obvious. Besides the dangers of cave-ins, when the burrows are wet, the silk does not dissociate and the hole maintains its shape. Unlined burrows collapse almost immediately when wet. Most insect species of Mediterranean climates, in contrast to *Cnemotettix,* pass the cold, wet winter months in diapause, and do not have to cope with the extremes of winter directly.

CNEMOTETTIX Caudell

Type species. — *Cnemotettix pulvillifer* Caudell

The species of *Cnemotettix* are morphologically quite similar to those of *Glaphyrosoma* although the two genera are chromatically dissimilar. All *Glaphyrosoma* species are brown, many so dark that they are almost black. They are never dorsally longitudinally striped, but may possess lateral stripes formed by a darkening of the distal portions of the thorax and abdominal tergites. *Cnemotettix* species are tan or grey brown and frequently possess two distinct longitudinal stripes. They are often setose and never highly lustrous whereas *Glaphyrosoma* crickets are never very setose and are always highly lustrous. Morphologically, *Cnemotettix* differs from *Glaphyrosoma* chiefly in the absence of any sort of auditory structure on the fore tibia. *Glaphyrosoma* species always possess an ovate auditory foramen on both surfaces of the fore tibia. The paraprocts of

FIGURES 7, 8. — Holes made by roots of *Ambrosia chamissonis* (7) on San Nicolas Island and hardened hole occupied by crickets (8) on Santa Rosa Island.

FIGURES 9, 10. — Cricket burrows among roots of *Ambrosia chamissonis* in soft sand. Fig. 9, of *C. spinulus* on San Nicolas Island; fig. 10, of *C. pulvillifer* on San Clemente Island.

the male genitalia are always more elongate and appear to be distally flattened in *Glaphyrosoma*. However, the similarity of the male genitalia of the two genera is striking. Both bear a pair of forward projecting teeth on the surface of the tenth tergite and the paraprocts always bear a spine on the outer margin. The subgenital plate is always scoop-shaped, apically truncate and with a pair of styles. The ovipositor of females of both genera lack teeth or other modification and the apex is always rounded. The sternal tubercle, characteristic of *Cnemotettix* species, does not appear to be present in *Glaphyrosoma,* although properly preserved material is not available.

GENERIC DESCRIPTION

Form rather robust, legs short, body length rarely exceeding 18 mm in male, 23 mm in female. Color brownish or greyish, dorsum darker with often a two-striped appearance. Lighter portions of body creamish white. HEAD: fastigium broad, without sulcus, dark colored, the pattern broken by light median stripe; pale ocellar spots laterally; eyes moderately large, little prominent, distinctly dorsoventrally elongate; antennae approximately one and one half times the length of the body; maxillary palpi distinctively long (figs. 4, 5, 6), the sensory membranous area extending along almost entire ventral surface.

PRONOTUM: narrowly marginate, in dorsal aspect broader than long, fore and hind margins weakly obtuse, more convergent cephalad than caudad; in lateral view fore and rear margins convergent ventrad, the ventral margin truncate, the ventrocephalic angle a little more broadly rounded than ventrocaudal. Abdominal tergites I-IX of male without modification; abdominal sternite six or seven female bearing a tubular structure, variously developed.

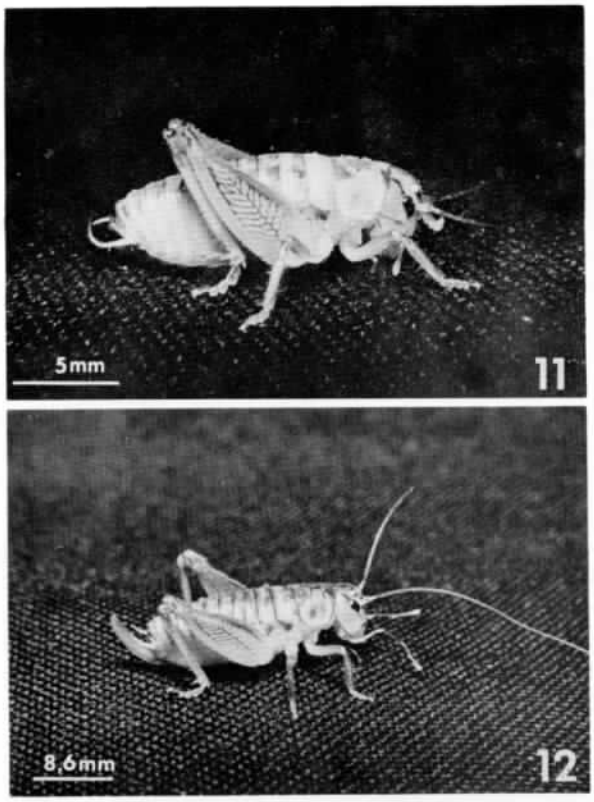
LEGS: short, stout, femora unarmed, without spurs on genicular lobes; tibia I armed on ventral surface with three evenly placed spines in apical one-quarter, a single additional spine located at end of proximal one-quarter on both margins; the internal (anterior) spine slightly more distally placed, dorsal surface armed solely with a pair of apical spurs; internal (anterior) surface of fore tibia frequently clothed with a dense mat of short setae concentrated along ventral margin. Tibia II armed dorsally with three evenly spaced spines (including calcars) along anterior margin, posterior margin with three spines, the proximal pair placed in basal one-third; ventral surface armed (exclusive of calcars) on anterior and posterior margins with two small widely spaced spines located in the distal third; apex of ventral surface with a pair of elongate calcars, the innermost (posterior) of which is fully one-third longer than the outermost and both of which are considerably longer than any of the other spines preceding them; entire surface of tibia II densely hirsute. Tibia III armed dorsally with 11-15 stout spines often separated by more minute tooth-like projections, ventral surface entirely unarmed; apex armed dorsally and ventrally with two pairs of apical spurs, the dorsal spurs elongate, nearly as long as the proximal three tarsal segments combined, bicarinate, the apex curved inward, dorsal spines separated by a distance equal to one and one-quarter that of the base of the proximal spur; ventral spurs much shorter than the

dorsal especially the internal pair which are subapical in position, innermost ventral spur one-quarter again as long as outermost. All tarsi four-segmented, distinctly laterally compressed; metatarsus bilobed mesad; ventroproximal sensory seta present on claws.

Terminal abdominal structures of male: cerci simple, conical, not modified as claspers. Tenth tergite modified, divided dorsad, apically truncate or bilobed, dorsal surface with a pair of anterior projecting sharp teeth. Paraprocts specialized, present as elongate clasping organs, bearing a subapical spine on outer margin, apex densely clothed with short setae. Subgenital plate broad from base to middle, sides thence parallel or divaricate, distal margin truncate, or angularly emarginate; short blunt styles present in all stages. Epiphallus poorly developed, unsclerotized; variously modified, with characteristic lateral projections.

Terminal abdominal structures of female: cerci like those of male. Subgenital plate elongate, distal margin distinctly convex. Ovipositor short, bud-like or elongate to 0.5-0.7 times as long as femur III; lateral valves broad, often broadened at apex; margins of ovipositor never serrate or modified in any way.

Five species of this genus are known, ranging on mainland California from Tijuana, Mexico north to the vicinity of Monterey Bay, and on all of the Channel Islands except Santa Barbara. All are geophilous, some with a preference for arenaceous habitats.



FIGURES 11, 12. — *Cnemotettix pulvillifer*. Fig. 11, last instar male, note pale coloration; fig. 12, adult female.

Cnemotettix pulvillifer Caudell
Figs. 2A, 2B, 3A, 3B, 4-6, 10-19.

Cnemotettix pulvillifer Caudell, 1916: 690.

Type data. — "San Clemente Island, Calif., T. H. Casey, Coll. U.S.N.M. Type no. 19965."

Type locality. — Caudell (1916) provides no further information concerning collection of the type series.

Deposition of types. — The holotype and allotype are in the United States National Museum.

Diagnosis. — Males distinctive in following characters: Tenth tergite distinctly bilobed, paraproct large, apex sparsely setose, external spine very large; subgenital plate short, apex broader than in any other species, apex shallowly excavate. Females may be recognized by the following: concealed tubercle of seventh abdominal sternite, elongate subgenital plate with acute apex, straight elongate ovipositor with acute apex. Basic color pattern dark, two-striped appearance poorly indicated; eye with black stripe heavy dorsally, faintly indicated ventrad of eye distinctly bifurcate at occiput. Entire insect setose. Distribution, figure 19.

Species description. — The type series is poorly preserved and badly shriveled. Since Caudell's description is brief, the species is fully redescribed with measurements of the holotype provided where possible.

MALE. — Size moderately large for genus, form moderately robust. Body surface dull, lacking luster, greatly hirsute (lost in holotype). HEAD: dorsoventrally elongate, genae truncate when viewed from anterior. Eye dorsoventrally elongate (1.20 × 0.80), moderately bulging, considerably less than twice as long as greatest width (1.20 × 0.80); fastigium little less than twice the width of first antennal segment (1.20 × 0.70), surface clothed with many

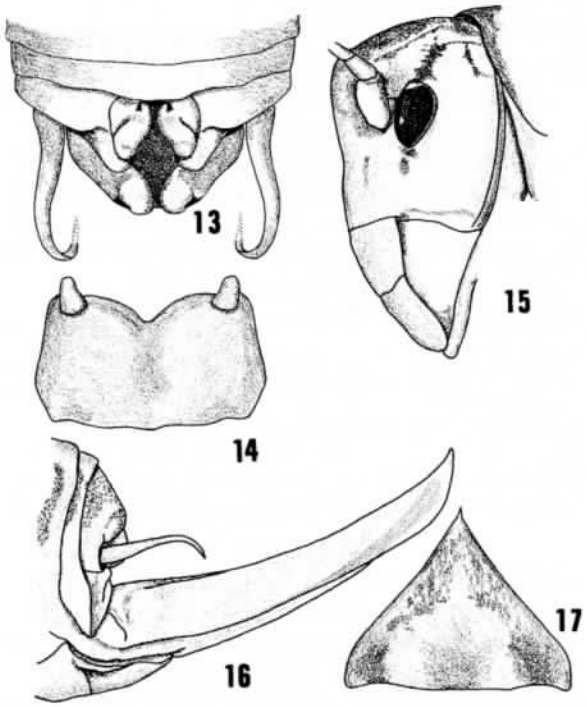
TABLE 3. — Table of principal characters in *Cnemotettix* species.

CHARACTER	SPECIES				
	bifasciatus	*spinulus*	*caudulus* *	*pulvillifer*	*miniatus*
Females					
Abdominal tubercle	Well indicated	Elongate	Well indicated	Concealed	Well indicated
Subgenital plate	Broader than long	Broader than long	Broader than long	Elongate	Broader than long
Ovipositor					
length [1]	7.31	8.82	1.80	7.50	6.40
ovip-fem ratio	0.578	0.079	1.81	0.070	0.024
apex	Blunt	Acute	Acute	Acute	Acute
Males					
Tenth tergite, apex	Truncate	Bilobed	Feebly bilobed	Bilobed	Feebly bilobed
Phallic lobes, lateral extensions	acutely pointed	acutely pointed	acutely pointed	elongate	rounded
Paraprocts					
setation	Dense	Sparse	Sparse	Sparse	Dense
spine	Small	Minute	Large	Very large	Moderate, erect
Subgenital plate					
length	Short	Broad	Long	Short	Long
median incision	Shallow	Shallow	Deep	Shallow	Moderate
Shared Characters					
coloration, base color stripes distinct (D) less distinct (L)	Light grey D	Grey brown D	Grey D	Dark Brown L	Grey D
Eye stripe	Testaceous "cap", feebly bifurcate	Two forks	One fork	One fork	Testaceous "cap", feebly bifurcate
Setation	Reduced	Reduced	Moderate	Moderate	Pronounced
Habitat	Chaparral	Coastal sand dunes, chaparral, Eucalyptus grassland	Fossilized sands, chaparral	Coastal sand dunes	Chaparral

[1] Average length

* Adult males not seen.

long setae; first antennal segment three times the length of second (0.90 × 0.30), internal margin obtusely produced in proximal one-quarter, this process feebly developed; second segment shorter than third, the latter more than two times the length of second (0.30 × 0.70); total length of antennae two and one-quarter times the length of the body. Segments of maxillary palpi as follows: proximal 1.70, mesal 2.10, distal 2.40; sensory area of distal segment occupying the apical one-third of same. THORAX: pronotum with distal border extending well beyond base of middle coxa when viewed laterally, ventral margin of lateral lobe truncate; surface of pronotum appearing embossed in region of white color markings; length of pronotum, when viewed laterally, slightly less than the combined length of the adjacent meso- and metathorax (2.70 × 1.00 × 0.80); margins of all thoracic nota with a thin mantle; fore and middle coxae each with a tooth, that of the former greatly produced, recurved ventrad, middle coxal tooth greatly reduced, hind coxa lacking any such tooth. Fore and middle legs armed in usual fashion for genus; hind tibia with 14 teeth on internal margin and 16 teeth on external margin, most teeth of equal length, a few smaller teeth scattered between the larger ones; prosternum bearing a pair of low broad projections, meso- and metanota with projections reduced, blunt. Internal surface of hind femur bearing seven or eight vertical rows of stridulatory "pegs" with a single, undulant transverse row in dorsal one-third. ABDOMEN with lateral portions of first two segments bearing stridulatory "pegs," the area occupied by these fully twice as great on the second segment than the first;



FIGURES 13-17. — Diagnostic structures in *C. pulvillifer*. Fig. 13, apex of abdomen and, fig. 14, subgenital plate of male; fig. 15, lateral view of head; fig. 16, lateral view of ovipositor and abdomen; fig. 17, subgenital plate of female. Magnification: figs. 13, 15, 16 12×; figs. 14, 17 25×.

tenth tergite as in fig. 13 deeply bilobed; paraproct elongate external spine large, four times longer than basal width; apex of paraproct sparsely clothed with long setae. Subgenital plate short, apex broad, broadest of any species; styles short, median incision shallowly V-shaped. COLORATION and SETATION. Head with vertex basically straw brown, mottled with darker fuscous; inverted Y-pattern present but very indistinct, mesal stripe with margins poorly defined, genae unmarked, frons with a pair of longitudinal fuscous stripes ventrad of fastigium; clypeus and labrum unmarked; eye black with fuscous stripe running from vertex beyond dorsum of eye, stripe immaculate dorsad, distinctly bifurcate at that point (fig. 15), stripe weakly diffuse beyond ventral margin of eye. Flagellum of antennae uniform fuscous throughout; first segment straw brown, obtuse projection fuscous. Dorsum of insect dark testaceous, striped appearance indistinct, much darker in mesal portions of meso- and metanota and first two abdominal tergites than in other dorsal portions of insect; lateral lobe of pronotum with reduced amount of cream-colored markings; lateral lobes of meso- and metanota lighter in median portions only, ventral margin infuscate; purpurescent blotch of thoracic nota relatively large on pronotum, less distinct on other nota; posterior one-third of abdominal tergites testaceous, also densely clothed with long sensory setae; sides of abdomen light grey contrasting with darker dorsum. All legs cream to grey in color, darker at base of fore tibia; middle femur with a short stripe on dorsal portion of inner face; hind femur typically marked, a short ventral stripe present in distal one-third. Setation pronounced; entire surface of body clothed with long setae; forelegs with dense short setae on ventral margin of anterior surface, this more diffuse in apical portion of tibia; median tibia hirsute but lacking the dense mat of short setae present on fore tibia, cerci and spurs of hind tibia.

FEMALE. — Similar to male except as follows. size slightly larger; tubercle of seventh abdominal sternite wholly concealed; subgenital plate elongate, slightly longer than broad, apex with acute digitiform process; ovipositor nearly straight, smooth, widest point at base, narrowed mesad, again widened near apex; tip acutely pointed; cercus relatively short, apex blunt, directed outward. Ovipositor straw brown in basal one-third, darkened in apical half, apical one-fourth dark brown.

Variation. — Not enough specimens have been examined to adequately comment on the degree of variation in this species. Size and coloration are similar among adults in the small series before us. The holotype bears only traces of color pattern because of poor preservation. The specimen labelled as the allotype is better preserved and clearly possesses the two dorsal longitudinal stripes.

Specimens examined. — All from San Clemente Island, Los Angeles County, California. No date 2 ♀ ♀, 1 second or third instar male, T. C. Casey, (holotype ♂, allotype ♀, USNM, type no. 19965, paratype ♀, ANSP); dunes near northwest harbor, elevation 75 feet, 27 June 1971 (D. C. Rentz, D. B. Weissman, 2 ♂ ♂, 4 ♀ ♀, collected as third and fourth instars, matured September 1971, ANSP); Wilson Cove, 200′ elevation, 28 June 1972 (D. B. Weissman, 1 ♂, nymph).

	Measurements (in mm)				
	Length body	Length pronotum	Breadth pronotum	Length femur III	Length ovipositor
MALE					
San Clemente *	11.4	3.4	2.4	9.1	
FEMALE					
San Clemente *	14.0	3.7	3.0	10.2	7.5
San Clemente, NW harbor	17.0	4.3	2.8	11.2	7.5

* Holotype, allotype.

Bionomics. — *C. pulvillifer* is locally abundant in sand dunes (fig. 18) vegetated by the prostrate composite *Ambrosia* (= *Franseria*) *chamissonis*. Its numbers appear to be considerably less, per unit area, than those of other species of the genus occupying similar habitats on other islands. A definite preference for sand in the proximity of *Ambrosia* roots, both alive and dead, was noted. No specimens were found in portions of the dunes where *Ambrosia* was not growing. However, a single juvenile cricket was collected in the coastal scrub plant community, under a rock, in the Wilson Cove area.

FIGURE 18. — Elevated sand dunes on San Clemente Island. Habitat of *C. pulvillifer*.

The majority of crickets were found in sand hills between six and ten feet in height where they occupied burrows (fig. 10) prominently exposed on the sides of the hills. Burrowing tenebrionids and spiders of the genus *Lutica* were also found with them. One of the spiders had apparently killed a small cricket and was observed feeding upon it in a silk-lined burrow. Whether the burrow was one of the spiders making or that of the cricket, was not determined.

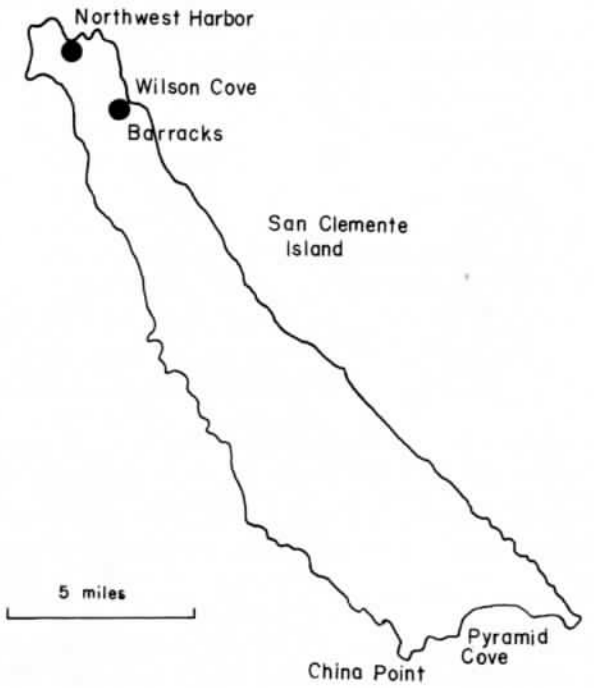


FIGURE 19. — Known distribution of *C. pulvillifer* on San Clemente Island.

Cnemotettix **miniatus** Rentz and Weissman, **new species, Figs. 20-25**

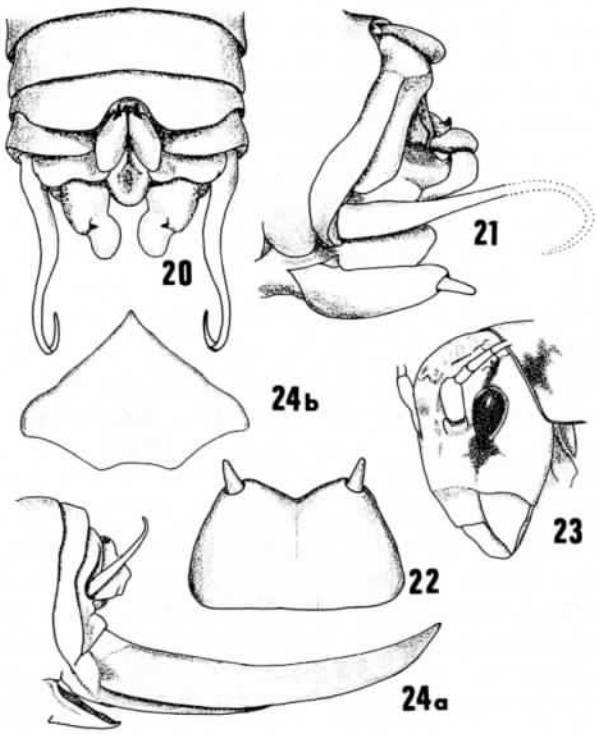
Type data. — "Tia Juana Hills, Mex., 21 VII 1931. E. R. Tinkham."

Type locality. — No further information is known concerning collection of the types.

Deposition of types. — The holotype and allotype (pinned) are in the Academy of Natural Sciences of Philadelphia.

Derivation of name. — This species is named for its small size.

Diagnosis. — Males are distinctive in the following characters: tenth tergite feebly bilobed; paraprocts large densely setose, armed with an erect, sharp spine; subgenital plate large, apex with V-shaped median incision. Females may be recognized by the following: tubular portion of seventh sternite visible externally; subgenital plate slightly broader than long, apex acute but without digitiform process; ovipositor elongate, gradually upcurved, apex acute. Basic color pattern grey or grey brown, two-striped; head with vertex testaceous; eye with stripe running through it, expanded beyond base, no trace of fork at base.



FIGURES 20-24. — Diagnostic structures in *C. miniatus*. Figs. 20, 21, apex of abdomen and, fig. 22, subgenital plate of male; fig. 23, lateral view of head and, fig. 24A, lateral view of ovipositor and abdomen and, fig. 24B, subgenital plate of female. Magnification: figs. 20, 21, 23, 24A 12×; figs. 22, 24B, 25×.

Species description. — HOLOTYPE MALE. Size small for genus (smallest known species), form attenuate, Body surface shining, lustrous, setose. HEAD round, genae laterally compressed. Eye dorsoventrally elongate, surface bulging more than any other species, about three-quarters longer than wide (1.10 × 0.70), of uniform width in dorsal three-quarters, in length nearly twice that of first antennal segment (1.10 × 0.7); fastigium more than twice as broad as first antennal segment (1.10 × 0.5), surface smooth; first antennal segment nearly six times the length of second (1.10 × 0.2), ventro-internal margin greatly produced forming a blunt tooth; second segment much shorter than the third, the latter three times the length of the former (0.60 × 0.20). Total length of antennae twice that of the body. Segments of maxillary palpi as follows: proximal 1.40, mesal 1.60, distal 1.90; sensory area of distal segment occupying apical one-sixth of same. THORAX: pronotum with distal margin extending to a point directly over median coxa when viewed laterally, ventral margin of lateral lobe truncate, surface of pronotum very smooth, only laterally appearing embossed; length of pronotum when viewed laterally slightly less than the combined length of adjacent meso- and metathorax (2.00 × 0.6 × 1.40); margins of all thoracic nota with a thin mantle; fore and middle coxae each with a tooth, that of the mesocoxa greatly produced; hind coxa with a small tooth. Fore and middle legs armed in the usual fashion; hind tibia armed with thirteen teeth on internal and twelve teeth on external margins, the first four or five in proximal position reduced in length; prosternum unarmed, mesothorax with a prominent transverse ridge, laterally flanged, metathorax with a pair of plates, acutely pointed apically. Stridulatory area of inner face of hind femur greatly reduced, consisting of three perpendicular rows of "pegs," the middle row with the greatest number (8), an ill-defined transverse row indicated in dorsal one-third. ABDOMEN with ventral portions of first two tergites with a reduced mat of stridulatory pegs, the region on the second tergite fully twice the area of that of the first; tenth tergite produced as in fig. 20, internal margin swollen, apex feebly bilobed; cerci greatly elongate, apex tapered, recurved, thread-like; paraprocts produced, armed dorsolaterally with an erect sharp spine, apex bulbous, densely setose; genitalia large, protruding beyond apex of abdomen, lateral lobes rounded; subgenital plate well developed, median length more than half that of basal width (1.0 × 1.7); median incision shallowly V-shaped, distance between styles 1.0, style 0.3. COLORATION and SETATION.

Head (fig. 23) with vertex straw brown with widely scattered blotches of testaceous, inverted Y-pattern indistinct on type, genae unmarked; frons with a pair of longitudinal broken testaceous stripes running from lateral edges of fastigium to median portion of frons; clypeus unmarked; eye grey with dorso-internal region white; vertex with a narrow black stripe running from beyond dorsum of eye, through eye, sparsely testaceous dorsad, without any trace of basal bifurcation (fig. 23), continuous beyond base of eye. Antennae straw brown, much lighter on first several segments, expanded portion of first segment and dorsum of second testaceous. Dorsum of insect with a thin but distinct cream-colored stripe continuous from anterior margin of pronotum to abdominal apex. Surface of insect distinctly two-striped only on anterior one-half, remainder less distinct; median portion of dorsum of insect uniformly straw brown; lateral lobe of pronotum with cream marking; lateral lobes of meso- and metanota light cream in median portion, ventral portion infuscate, this most obvious on metanotum. All tibia straw brown or creamish except proximal portion with a light fuscous annulus; fore and middle femora basically cream, but with an indistinct purpurescent area near apex; hind femur with characteristic pattern, feebly indicated because of preservation, ventral border with a distally forked longitudinal stripe. Setation pronounced, especially on appendages; fore tibia with anterior ventral margin with a row of dense short setae increasing in length and number from base to apex; cerci and spurs densely clothed with long setae.

ALLOTYPE FEMALE. — Similar to male except as follows: size much larger; basal portion of seventh abdominal sternite with tubular projection visible externally, not as well developed as in *C. bifasciatus;* subgenital plate slightly broader than long (2.0 × 1.7), apex acute, without digitiform process; ovipositor elongate (7.1) gradually curved upward, smooth, distinctly narrowed in median region of distal one-third (0.70), widest point in basal one-third (1.2), apex acute, tapered gradually beyond narrowed area. Coloration similar to that of male but somewhat darker in overall appearance.

Variation. — The topotypic series shows little variation in structure and coloration. This series appears to have been originally preserved in liquid and subsequently dry mounted. As a result the brown colors have somewhat changed to grey. The female from Carmen and the other specimens show more brown in their color pattern. The last instar male from Santa Catalina Island bears a distinct basal fork in the eye stripe. This is clearly absent from all mainland specimens of this species and the other two females from that Island. The adult female from Santa Catalina shows the dorsal longitudinal striping pattern a little more completely than any other specimen. However, the stripes are much heavier on the anterior three-quarters of the body than on the distal one-quarter.

The single female from San Nicolas Island is placed here with some reservation. With respect to size it falls well within the range of this species. It is definitely not *C. spinulus,* the species herein described as abundant on the sand dunes of that island. This female was found on a cloudy day at 4:15 P.M. (PDST) on a gravel road adjacent to a coastal sage habitat near the naval barracks. This specimen, definitely an adult because it laid eggs in the laboratory, differs from others of *C. miniata* chiefly on the basis of color pattern around the eye. The stripe is very narrow (fig. 23) and forked laterally at the base. This fork is very poorly indicated and obsolete after only a very short distance. The main portion of the stripe is continuous through the eye but diffuse just beyond the base of the eye. The dark coloration typical of the thoracic nota is similarly reduced rendering the lateral portions of the plates very light in color. The structure of the stridulatory pegs, the subgenital plate and the distally narrowed ovipositor are also comparable with that considered typical of *C. spinulus.*

Specimens examined. — CALIFORNIA: LOS ANGELES COUNTY: Santa Catalina Island, Middle Ranch, bunk house area, 700 feet elevation, 2 July 1972, female matured late August, 1972 (D. B. Weissman, 1 ♂ last instar, 1 ♀ last instar, 1 ♀ adult). MEXICO: ESTADO DE BAJA CALIFORNIA: Tijuana Hills, 21 July 1931 (E. R. Tinkham, holotype ♂, allotype, 1 ♀ paratype. Questionable locality data: "Carmen," California, 30 December 1922 (C. L. Hubbs, 1 ♀, paratype, UMMZ). Questionable placement: CALIFORNIA: VENTURA COUNTY: San Nicolas Island, U.S. Navy barracks, 400 feet elevation, 15 August 1969 (D. B. Weissman, 1 ♀).

FIGURE 25. — Known distribution of *C. miniatus* on Santa Catalina Island.

Bionomics. — There is no information available concerning collection of the types in Mexico, but on Santa Catalina Island, all specimens were found at night attracted to oatmeal in the chaparral plant community. Dominant plants in this area include scrub oak, *Artemesia* and *Rhus ovata.* The soil is hard and rocky, not sandy, with a moderate amount of accumulated leaf litter present in the pure *Quercus dumosa* area.

The single immature male compares well with the adult holotype. The spine of the paraproct is the largest for any species in the genus.

Discussion. — *C. miniatus* is the smallest known species in the genus. Its distribution presents the southernmost record of any *Cnemotettix* species. The type series might be mistaken for a collection of nymphs were it not for the development of the genitalia of the male and the development and sclerotization of the ovipositor of the female. This species illustrates the least amount of development of the stridulatory area. Nymphs of other species illustrate greater development of this character than adults of this species. The sternal tubercle of the female is wholly visible, though much less tubular than found in *C. bifasciatus.* Poorly preserved or shriveled dry mounted specimens often have this character concealed.

Cnemotettix **bifasciatus** Rentz and Weissman, **new species, Figs. 26-35**

Type data. — "Calif. Monterey Co., Pfeiffer — Big Sur St. Park, on Big Sur River nr. Big Sur. 18.IX. 1967. T. H. Hubbell #7B."

Type locality. — The exact location concerning collection of the type series by Hubbell (in litt.) is as follows: "#7B . . . along the nature trail and beyond on the west bank and slope of the Big Sur River and along its sandy and rocky margins . . ." Elevation between 200 and 400 feet.

Deposition of types. — The holotype and allotype are deposited in alcohol in the University of Michigan, Museum of Zoology.

Derivation of name. — This species is named with reference to its two-striped appearance.

Diagnosis. — Males are distinctive in the following characters: tenth tergite with apex truncate, not bilobed; paraprocts large, densely setose, armed laterally with a small spine; subgenital plate short, median incision shallowly V-shaped. Females may be recognized by the following: tubular portion of seventh sternite elongate, clearly visible externally;

	Measurements (in mm)				
	Length body	Length pronotum	Breadth pronotum	Length femur III	Length ovipositor
MALE					
Tiajuana Hills *	10.7	2.7	2.0	8.1	
Last instar, Santa Catalina	12.0	3.2	2.2	8.4	
FEMALE					
Tiajuana Hills *	15.5	3.3	2.5	9.9	7.1
Tiajuana Hills *	9.5	3.0	2.3	8.6	6.5
"Carmen"	9.1	3.0	2.4	9.2	5.1
Santa Catalina	14.5	3.3	2.6	10.6	7.7
Last instar, Santa Catalina	15.2	3.5	2.6	9.9	5.6

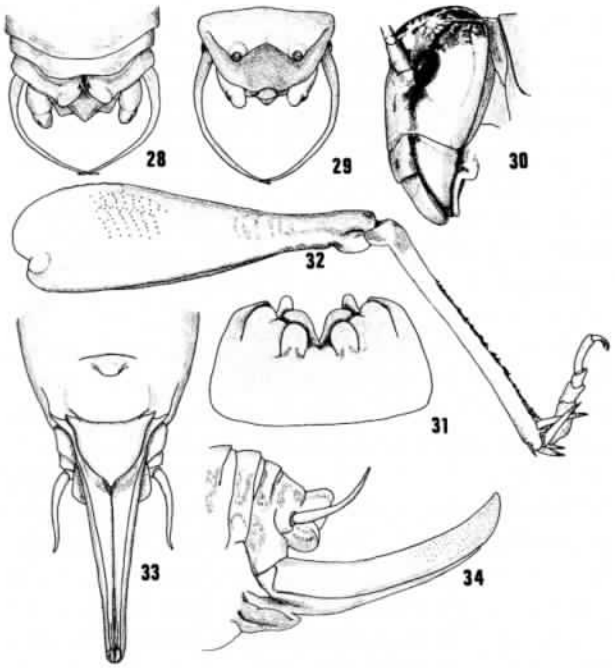
* Holotype, allotype.

FIGURE 26. — Santa Monica Mountains habitat of *C. bifasciatus*. Chamise, *Adenostoma fasciculatum* is the predominant plant.

FIGURE 27. — Santa Monica Mountain habitat of *C. bifasciatus*. Note chaparral vegetation and rocky substrate.

subgenital plate broader than long; ovipositor elongate, straight. Basic color pattern brown or grey brown, all stages distinctly two-striped; entire vertex of head to region of eye stripe testaceous; eye with stripe running from vertex to and through eye feebly but distinctly bifurcate dorsally. Distribution, fig. 35.

Species description. — HOLOTYPE MALE. Size large for genus, form robust. Body surface dull, lacking lustre, not setose. HEAD cordate, genae not appreciably swollen. Eye dorsoventrally elongate, slightly less than twice as long as wide (1.00 × 0.65), its greatest width in dorsal one-third, in length equal to that of first antennal segment; fastigium slightly less than twice as broad as width of first antennal segment (1.35 × 0.70), surface smooth; first antennal segment more than three times the length of second (1.15 × 0.3), internal margin produced mesad forming a blunt tooth; second segment shorter than third, the latter approaching twice the length of the former (0.55 × 0.30). Total length of antenna two and one half times the length of the body. Segments of maxillary palpi as follows: proximal 1.90, mesal 2.40, distal 2.90; sensory area of distal segment occupying the apical one-third of same. THORAX: pronotum with distal border extending to a point median of fore and middle coxae when viewed laterally, ventral margin of lateral lobe truncate, surface of pronotum appearing embossed in region of white color markings; length of pronotum, when viewed laterally, slightly less than the combined length of adjacent meso- and metathorax (2.60 × 1.20 × 1.30); margins of all thoracic nota with a thin mantle; fore and middle coxae each with a prominent tooth, hind coxa with a reduced but sharper tooth. Fore and middle legs armed in the usual fashion, hind tibia armed with 16 teeth on internal and 18 teeth on external margins, alternating in length between a very large tooth and a much smaller one; prosternum bearing a pair of low, broad projections, meso- and metathorax with prominent projections, the former much better produced. Internal surface of hind femur bearing five vertically diagonal rows of stridulatory "pegs" with a transverse row located in the dorsal one-third. ABDOMEN with lateral portions of first two segments bearing stridulatory "pegs," the region occupied by these fully twice as great on the second segment than the first; tenth tergite produced as in fig. 28, the internal margin truncate, apex broadly obtuse; cercus greatly elongate (approximately 4.9 mm in length) tapering to apex which is thread-like; paraprocts produced, armed laterally with short spine, directed inward, apex bulbous, densely setose; genitalia large, protruding noticeably beyond apex of abdomen, lateral lobes sharply pointed; subgenital plate short, median length less than half the basal width (1.50 × 3.20); median incision shallowly V-shaped, distance between styles 1.40, style 0.4, distal margin of subgenital plate sparsely setose. COLORATION and SETATION. Head (fig. 30) with vertex testaceous fastigium broken with inverted Y-pattern with a narrow median stripe mesad, genae unmarked, frons marked with a pair of longitudinal testaceous short stripes ventrad of fastigium; clypeus marked with a linear pair of spots ventrad of each of the stripes, labrum unmarked; eye black with a stripe running



FIGURES 28-34. — Diagnostic structures in *C. bifasciatus*. Fig. 28, dorsal and, fig. 29, ventral view abdomen male; fig. 31, genitalia of male; fig. 30, lateral view head; fig. 32, leg; fig. 34, ovipositor and abdomen of female; fig. 33, ventral view apex of abdomen including sternal tubercle. Note stridulatory pegs on inner face of femur on fig. 32. Magnification, figs. 28-32, 33, 34, 12×; fig. 31 25×.

from vertex to beyond dorsum of eye, this stripe heavily clouded with testaceous dorsally, and feebly but distinctly bifurcate at that point (fig. 30), stripe weakly divergent laterad at base of eye, stripe diffuse beyond ventral margin of eye. Antennae light cream-colored on dorsal and external margins, considerably darker, especially in obtuse projection of first segment. Dorsum of insect with a thin light cream-colored longitudinal stripe preceding unbroken from anterior margin of pronotum to abdominal apex. Surface of insect distinctly two-striped, the stripes formed by dark brown areas bordered by cream-colored regions; median portion of insect dorsally lighter; lateral lobe of pronotum with irregular cream-colored markings; lateral lobes of meso- and metanota light cream for nearly entire ventral half, this only interrupted by a small purpurescent blotch; distal one-third to one-quarter of abdominal terga purpurescent, this area similarly clothed with sensory setae. All legs marked most prominently in basal portion of each tibia, this forming a narrow, indistinct dark annulus; femora faintly darker brown on anterior, ventral borders; hind femur marked as typical in many representatives of this family, this pattern not followed or emphasized by setation, ventral margin with feeble but distinct stripe. Setation overall reduced; fore tibia with internal ventral border with an increased number of long setae, there in one or two rows, more dense at apex; cerci and spurs of hind tibia setose.

ALLOTYPE FEMALE. — Similar to male except as follows: distinctly larger; basal portion of seventh abdominal sternite with a prominent tubular projection, directed posteriorly, apex open, projection in no way concealed by preceding sternite; subgenital plate broader than long (3.20 × 2.00), apex with a digitiform process; ovipositor straight, smooth, widest point in basal one-third (7.70 × 1.60), apex sharp, ventral portion obtuse near apex; cercus relatively short (0.30), apex blunt. Coloration similar to that of male, ovipositor dark brown or testaceous, ventral margin in proximal one-half cream-colored.

Variation. — There is little variation in size or color among adult individuals in the large series from Big Sur State Park. Some specimens show a more intense contrast in the color pattern than others but this may be related to the age of the individuals. The degree of intensity of the bifurcation of the eye stripe is somewhat variable as to intensity, but it is always present, though sometimes broken. Similarly, the light markings of the vertex are always present in the pattern as illustrated (fig. 30) but the bordering darker areas may vary in their intensity. This species is known from a relatively broad geographic area, though adult material is available from only a few localities (see records). There is no detectable degree of significant variation from the above with the exception of coloration and as noted below. The two individuals from Arroyo Seco, 1-IV-1965, possess a larger blotch on the lateral lobe of the meso-and metanota; the ventral margin of these lobes is also somewhat darkened.

Two adult individuals from the mainland of California offer problems. The male from Kirk Creek, Monterey County is considerably smaller than any other adult male individual seen representing this species. The dorsal bifurcation of the eye stripe is faint, but present, and the surface of the body is considerably more hirsute than is normal for the species.

The cerci are distinctly directed outward as opposed to upward in all the other examples but this may be a matter of preservation. The two-striped dorsal pattern is present but considerably less pronounced than seen in the other specimens.

A female from the Morro Bay dunes is similarly smaller in size and lacks the protruding tubular structure on the seventh abdominal sternite. This structure, however, is present but greatly reduced. In other respects this individual agrees with the description of the species and its small size may be an indication that it is a last instar nymph. However, the high degree of sclerotization and the relative development of the subgenital plate seem to preclude this consideration.

Specimens examined. — CALIFORNIA: LOS ANGELES COUNTY: Santa Monica Mts. 1825 feet, Mulholland Hwy. and Decker Road 24 June 1972 (D. B. Weissman, 1 ♀, matured 7 Oct. 1972). San Gabriel Mts., Tanbark Flat, 20 June 1952 (W. J. Gertsch, 2 ♀ ♀, last instars, AMNH). MONTEREY COUNTY: Arroyo Seco, 1 May 1965 (W. E. Ferguson, 2 ♂ ♂, UMMZ). Asilomar (1.3 miles west Pacific Grove), 20 feet elevation, 7 July 1957, (T. J. Cohn, #24, 1 ♀, third instar, UMMZ). Carmel, 500 feet elevation, 30 June 1957 (T. J. Cohn, #21, 2 ♀ ♀, antepenultimate instars, UMMZ); 1.5 miles north, 700 feet elevation, 23 June 1957 (T. J. Cohn, #16, 1 ♂, 2 ♀ ♀ all antepenultimate instars, UMMZ). Junipero Serra Peak, 5,700 feet elevation, 11 August 1956 (H. B. Leech, 2 ♂ ♂, CAS). Kirk Creek, 15 October 1966 (W. C. Gagne, 1 ♂, ANSP). Pfeiffer — Big Sur State Park, on Big Sur River, near Big Sur, 18 September 1967 (T. H. Hubbell, #7A, #7B, 5 ♂ ♂, 8 ♀ ♀, 2 ♀ nymphs, UMMZ). RIVERSIDE COUNTY: Idyllwild, 7 July 1953 (W. J. and J. W. Gertsch, 1 ♀, AMNH); 17 June 1952 (W. J. and J. W. Gertsch, 1 ♀, AMNH). SAN LUIS OBISPO COUNTY: Cambria, 23 June 1952 (M. A. Cazier, W. J. Gertsch, R. Schrammel, 2 ♀ ♀ antepenultimate instars, AMNH). Morro Bay dunes, 30 January 1965, (T. J. Cohn, #4, 1 ♀, UMMZ). SANTA BARBARA COUNTY: Gaviota, 5 miles east, 17 July 1953 (W. J. and J. W. Gertsch, 1 ♀, last instar AMNH). VENTURA COUNTY: Los Padres National Forest Wheeler Gorge Camp, 9 miles north Ojai on Highway 33, 1700 feet elevation, 13 September 1967 (T. H. Hubbell, #1, 2 ♂ ♂, UMMZ).

FIGURE 35. — Known distribution of *C. bifasciatus* on mainland California.

Bionomics. — *C. bifasciatus* is apparently rather tolerant of a wide range of habitat types throughout its distribution. The fieldnotes of Hubbell (in litt.) provide further information on the type locality of this species and are as follows: Ventura County: . . . "taken on the slope of the ridge where oaks were mixed with chaparral, on dry sandy soil. No others seen. Occurred with *Pristoceuthophilus pacificus.* Monterey County: Pfeiffer — Big Sur: "This park includes part of the valley of Big Sur River — here shallow, rocky bottom, 20-40 feet wide, with sandy banks and terraces, and sandy-rocky slopes covered with redwood forest (in groves), oaks, California laurel, etc. Oatmeal and peanut butter trails were set, each using a large carton of oatmeal, each one-half to three-quarters mile long. #7A. Trail began in valley of small creek on east side of park entrance and ran up the creek along the trail to a falls, then branched off on the Oak Grove trail. In the creek

	Measurements (in mm)				
	Length body	Length pronotum	Breadth pronotum	Length femur III	Length ovipositor
MALE					
Big Sur *	17.5	3.3	2.6	10.7	
Big Sur	19.5	3.3	2.6	11.9	
Big Sur	17.6	3.2	2.6	11.0	
Big Sur	18.0	3.2	2.9	11.5	
Arroyo Seco	16.3	3.5	2.6	11.4	
Arroyo Seco	19.0	4.0	3.0	12.1	
FEMALE					
Big Sur *	22.0	4.4	3.60	14.0	7.5
Big Sur	21.5	3.9	3.20	11.6	7.0
Big Sur	22.2	3.8	3.20	13.0	7.5
Big Sur	22.5	4.2	3.70	13.0	7.7
Big Sur	23.0	4.1	3.20	13.1	7.8
Big Sur	23.0	3.8	3.1	12.0	7.0
Big Sur	23.5	4.0	3.0	×	7.6
Big Sur	23.5	4.7	3.0	13.7	8.2
Big Sur	22.8	4.0	3.3	12.9	7.0
Morro Bay dunes	17.5	3.3	2.6	10.5	6.1

* Holotype, allotype.

valley the bait trail was on a path shaded by redwoods and oaks; higher up it was drier with only oaks and underbrush on the hillside. The ground litter was redwood duff along the sides in the valley, thin oak leaf and grass cover among trees on hillside. The area was dry except near the stream. Along the trail the following orthopterous species were taken: *Pristoceuthophilus* sp., *Neduba* sp., and *Cnemotettix* sp., the latter only in the oak zone.

"7B. Trail of oatmeal along the "nature trail" and beyond, on the west bank and slope of Big Sur River as stated in the type locality section. The *Cnemotettix* were most numerous on the sand flats along the stream where it is bordered by oaks, laurel, *Baccharis pilularis,* white alder, Platanus, willows, and big-leafed maples." The total collecting time at the above collecting sites was from 5:30 p.m. to midnight.

At the site listed 1.5 miles north of Carmel, Cohn states that the *Cnemotettix* crickets were taken either at an oatmeal trail or near a road in thin low grass at 10:00 p.m. The area is described as open grazed woods on one side of the road with a ravine and pine woods and weeds on the other. One of the most interesting records of *C. bifasciatus* is that from the Morro Bay dunes. No information other than that *Rhachocnemis,* a camel cricket, was present.

A single immature individual was found four feet from the ground on the very top of a introduced mint, *Marrubium vulgare.* The exact location of this observation is at the corner of Decker road and Mulholland Highway, elevation 1825 feet in the Santa Monica Mountains. The time was 11:15 p.m. (PDST) on 24 June 1972. The area was densely vegetated by typical chaparral plants. Also found here at night with *Pristoceuthophilus* sp. and *Ceuthophilus californianus.* Only the latter two species were attracted to oatmeal.

In other portions of the Santa Monica Mountains, *C. bifasciatus* was not found. This includes Pt. Mugu State beach and numerous other sand dune areas along the coast.

Cnemotettix **caudulus** Rentz and Weissman, **new species, Figs. 36-50**

Type data. — "CAL. Sta. Barbara Co., Santa Rosa Island, Skunk Point, dunes, 2-VII-1971. D. C. Rentz, D. B. Weissman collectors.

Type locality. — The type locality is a fossilized

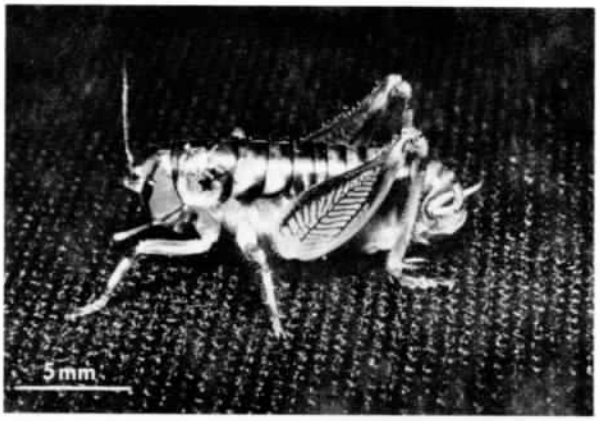


FIGURE 36. — Adult female of *C. caudulus*. Note abbreviate ovipositor.

FIGURE 37. — Type locality of *C. caudulus* on Santa Rosa Island.

sand dune (fig. 37) located approximately one-half mile from the beach at Skunk Point. Skunk Point is on the eastern coast of Santa Rosa nearly five miles from Santa Cruz Island.

FIGURE 38. — View of area near habitat of *C. caudulus* on San Miguel Island.

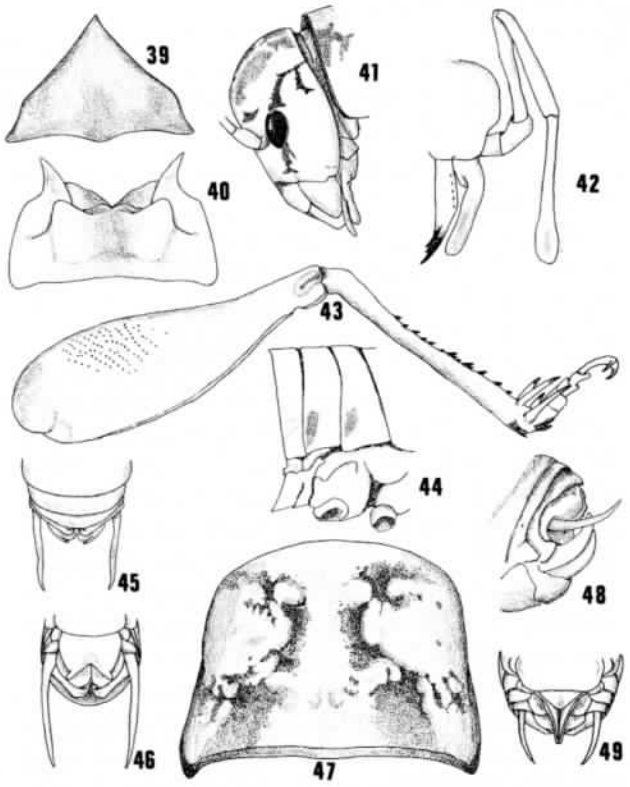
Deposition of types. — The holotype and allotype are deposited in alcohol in the Academy of Natural Sciences of Philadelphia.

Derivation of name. — This species is named for its greatly reduced ovipositor.

Diagnosis. — Males distinctive in following characters: tenth tergite feebly, if at all bilobed, paraproct large, apex setose, external spine large; subgenital plate large, median incision deep. Females may be recognized by the following: tubercle present at apex of sixth sternite, visible externally; subgenital plate broader than long, apex acute; ovipositor short, barely surpassing apex of abdomen. Basic color grey, two-striped appearance well indicated in juveniles, less pronounced in adults; eye with stripe running from vertex to clypeo-labral suture, a narrow fork present at base. Setation pronounced by not as dense as in *C. pulvillifer*. Distribution, fig. 50.

Species description. — HOLOTYPE FEMALE. Size large, form robust. Body surface dull, sparsely setose. HEAD dorsoventrally elongate, genae tumescent. Eye elongate (1.10 × .55), external margin concave mesad, internal margin truncate; surface moderately bulging, in length slightly more than that of first antennal segment (1.10 × 0.80); fastigium broad, twice as broad as first antennal segment (1.70 × 0.70), surface smooth; first antennal segment nearly four times the length of second (1.10 × 0.30); internal margin produced mesad for entire length; second segment much shorter than third, the latter nearly twice the length of former (0.6 × 0.3). Total length of antennae two and one-half times the

length of body. Segments of maxillary palpi as follows: proximal 1.60, mesal 2.25, distal 2.65; sensory area of distal segment occupying apical one-quarter of same. THORAX: pronotum with distal margin extending to a point directly over median coxa when viewed laterally, ventral margin of lateral lobe truncate, of pronotum smooth, sculpture pattern indicated solely by color; length of pronotum when viewed laterally much less than twice the length of adjacent meso- and metathorax (2.80 × 1.50 × 1.80); margins of all thoracic nota with a relatively broad mantle; fore and middle coxae each with a poorly developed tooth, that of the mesocoxa very feebly produced; hind coxa without any indication of a tooth. Fore and middle legs armed in usual fashion; hind tibia armed with ten teeth on internal margin, external margin with twelve teeth, all teeth of nearly uniform development; prosternum with a pair of triquetrous projections; meso- and metathorax each with a pair of projections. Stridulatory area of inner face of hind femur (fig. 43) with seven complete perpendicular rows of "pegs", a single ill-defined transverse row present in dorsal one-third. ABDOMEN with ventral portions of first two tergites densely packed with a mat of stridulatory pegs, the area of the second tergite slightly greater than that of first. Tubular projection protruding distad from apical portion of sixth sternite, visible externally; subgenital plate broader than long (2.20 × 0.80), apex truncate, folded inward in type but apically acute; ovipositor greatly reduced (1.50) in length only slightly extending beyond abdominal apex. COLORATION and SETATION. Basic color grey, not brown. HEAD (fig. 41) with vertex very lightly testaceous, inverted Y-pattern ill defined, obsolete, median stripe of vertex better indicated; frons with a very faintly indicated pair of internal stripes; vertex with a narrow black stripe running from beyond dorsum of eye, through eye and ventrad to clypeolabral suture, base of stripe with a narrow, undulant fork; margins of eye stripe irregular; testaceous portion of vertex not extending to region of eye stripe. Eye black, dorso-internal corner white. Antennae fusco-testaceous, first segment cream, internal margin somewhat darker, second and third segments darker; entire surface of flagellum of antenna densely setose. Dorsum of insect generally greyish, median portion of abdominal tergites with two white markings per tergite; two striped appearance obliterated; lateral lobe of pronotum with extensive cream area; lateral lobes of meso- and metanota with extensive light area, fuscous dorsally. All tibia cream, dorso-internal margin fuscous, no annulus; middle femur with three light fuscous stripes; hind femur with characteristic pattern, ventral border with heavy longitudinal stripe. Setation pronounced, but not as great as in other species such as *C. pulvillifer*; fore tibia with ventral portion of anterior margin with several rows of short setae; cerci and spurs densely clothed with long setae.



FIGURES 39-49. — Diagnostic structures in *C. caudulus*. Fig. 39, subgenital plate female; fig. 40, genitalia of male; fig. 41, lateral view head female; fig. 42, maxilla of female; fig. 43, right hind leg male, note pattern of stridulatory pegs on inner surface; fig. 44, lateral view of meso- and metathorax of male showing stridulatory pegs; figs. 45, 46 dorsal and ventral views apex of abdomen of male; fig. 47 dorsal view pronotum male; figs. 48, 49 lateral and ventral views apex of abdomen of female. Magnification figs. 41, 44-49 12×; figs. 39, 42, 43 25×; fig. 40 50×.

Description of male. — Adult males of *C. caudulus* have not been collected. Last instar topotypic nymphs possess the following distinctive features:

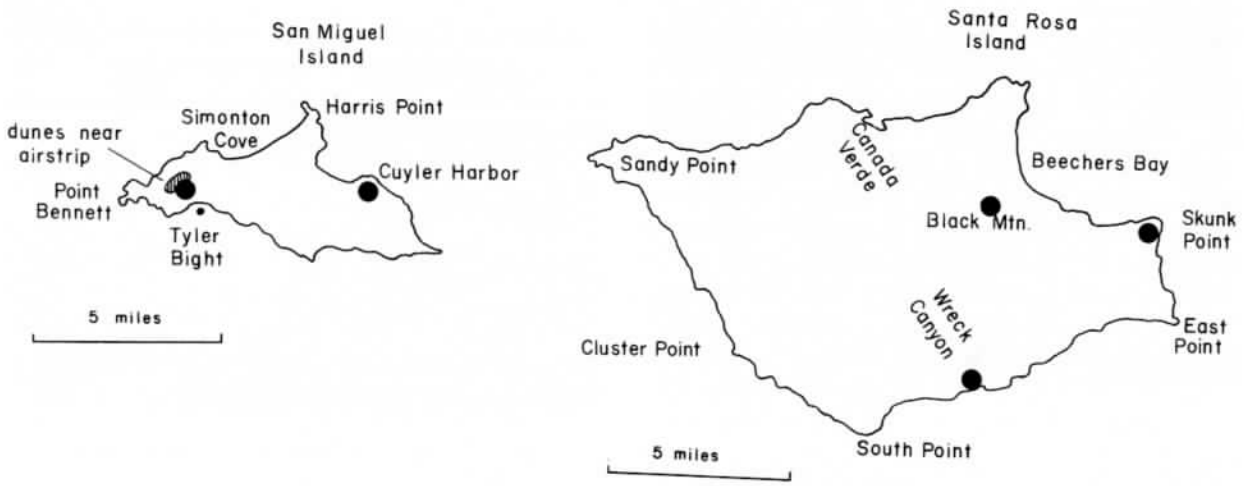


FIGURE 50. — Known distribution of *C. caudulus* on San Miguel and Santa Rosa Islands.

tenth tergite produced as in fig. 49, internal margin not bilobed; cerci elongate, tapering, in situ apical one-third directed outward; paraprocts armed dorsolaterally with an elongate spine, apex somewhat bulbous, setation undeveloped; genitalia protruding, apices of lateral extensions acutely produced; subgenital plate well developed, median incision deep.

Variation. — This species is known from two islands and little morphological variation has been detected. Some mature specimens (females) are a little lighter than as described for the holotype but this is attributed to individual rather than geographical variation since a gradation may be seen amongst a series from the type locality. As in many other species in this genus, nymphs of *C. caudulus* are much lighter in color than adults.

Specimens examined. — CALIFORNIA: SANTA BARBARA COUNTY: Santa Rosa Island, Skunk Point, dunes, 2 July 1971, elevation 100 feet. (D. C. Rentz, D. B. Weissman, holotype ♀, 5 ♂ all nymphs.); Wreck Canyon, elevation 5′, sand dune area on coast, 3 July 1971 (D. C. Rentz, D. B. Weissman, 1 ♂ last instar, 1 ♀); Black Mountain, 1298 feet elevation, 4 July 1971 (D. C. Rentz, D. B. Weissman, 1 ♀ penultimate instar); no precise locality on island (1 ♂, young instar, USNM no. 26662). San Miguel Island, dunes near airstrip, elevation 300 feet, 13 July 1971 (D. C. Rentz, D. B. Weissman, 2 ♂, 3 ♀ ♀, 7 nymphs); 21, 22 July 1972 (D. B. Weissman, 2 ♂ ♂, 2 ♀ ♀); Cuyler Harbor, 8-13 July 1970 (D. R. Miller, 1 ♀, last instar, USNM).

Bionomics. — On Santa Rosa Island, *C. caudulus* was found in greatest abundance at Skunk Point dunes. It occurs a half mile or so from the beach in a fossilized dune area. Because of the hard sand and limited digging ability of the crickets, it seems likely that some other animal originally constructed the burrows. On several occasions this species was found in burrows with adults and nymphs of *Ceuthophilus californianus*, which apparently can dig holes in this area. In this situation, the burrows were considerably larger than normally encountered with either species of these burrowing crickets, and they were not usually lined with silk. On San Miguel Island similarly large holes were found in fossilized sand dunes. On careful digging, the initial large entrance hole was subsequently found to branch to side tunnels which were smaller. Here *Ceuthophilus* and *Cnemotettix* were found but the species were never mixed in any single branch. *Ceuthophilus* individuals occurred together, but then always (three observations) a mature male and female. In soft sandy areas with *Ambrosia* roots, *Cnemotettix* and *Ceuthophilus* each had their own separate complete tunnels, although one observation revealed the species within six inches of one another. The large holes in fossilized dunes may simply have been there for several years, during which time wind and root action may have enlarged them. Since the sand is so hard, the need for silk to stabilize is reduced.

There is considerable evidence that *C. caudulus* may inhabit holes not made by the crickets themselves. In areas of fossilized sands on San Miguel

and Santa Rosa holes made by the roots of *Ambrosia chamissonis* remain for a considerable period after the roots have long since decayed. Exposed roots are whipped by the wind (fig. 8), creating much larger holes supposedly suitable for the crickets and other organisms. As the root decays, a ready-made habitat is provided for dune insects. The low average rainfall on San Miguel of 12.79″ averaged for 36 years (data unavailable for Santa Rosa) would tend to leave such holes intact for considerable periods, thereby permitting them to be used by the crickets.

The action of mice, *Peromyscus maniculatus,* may also account for the enlarged entrance holes.

Of interest is the single record of this species away from a dune habitat. The female from Black Mountain was found under a rock (no evidence of spun silk), not in a burrow, on a bare rocky knob in a region vegetated chiefly by chamise, *Adenostoma fasciculatum* and scrub oak *Quercus dumosa.* Repeated searching, both on Black Mountain and other similar areas, failed to yield additional specimens.

No specimens of *C. caudulus* maintained in the laboratory laid eggs, nor were any eggs collected in the field. The short bud-like ovipositor appears to be adapted for oviposition in the fossilized sand habitat where an elongate ovipositor might be incapable of penetration into the hard surface of a burrow. The sparse occurrence of the species elsewhere on the island may indicate that the sand dunes are the presently preferred habitat.

Cnemotettix **spinulus** Rentz and Weissman,
new species, Figs. 51-64

Type data. — "Calif. Ventura County, San Nicolas Island, 15 July 1972, matured early September 1972."

Type locality. — The exact locality (fig. 52) where the types were collected is a sand dune area 0.6 miles southeast of Celery Canyon along the paved road, elevation 575 feet. The dunes are stabilized by a reed-like grass and *Ambrosia chamissonis.*

Deposition of types. — The holotype and allotype (in alcohol) are deposited in the Academy of Natural Sciences of Philadelphia.

Derivation of name. — This species is named with reference to the reduced spine on the external margin of the male paraproct.

FIGURE 51. — Adult female of *C. spinulus.*

FIGURE 52. — Type locality of *C. spinulus* on San Nicolas Island.

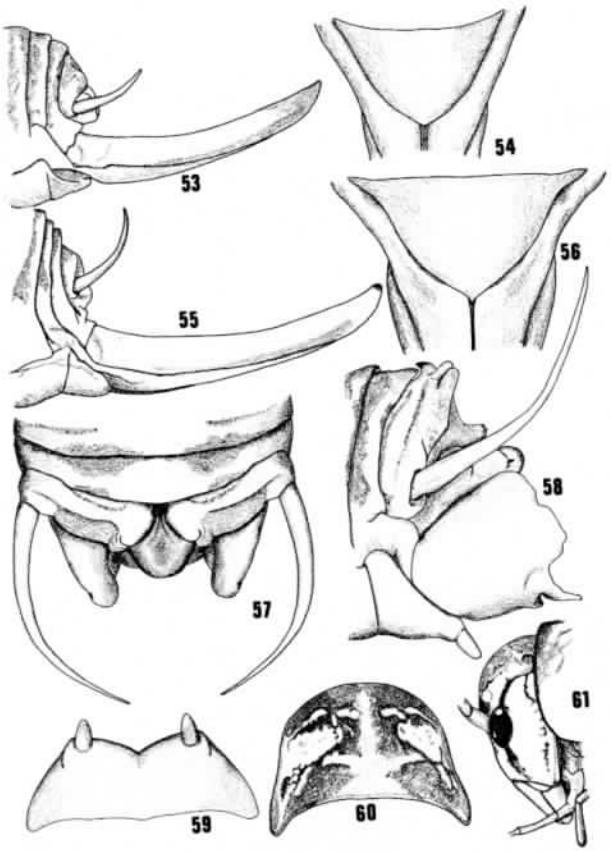
Diagnosis. — Males distinctive in following characters: tenth tergite with apex bilobed; paraproct greatly produced, sparsely setose, armed laterally with a minute spine; subgenital plate broad, median incision shallow. Females may be recognized by the following: tubercle of seventh sternite elongate, plainly visible externally; subgenital plate broad, apex obtuse; ovipositor directed upward, apex acute. Coloration dark grey brown, two-striped appearance distinct in all stages. Eye with stripe running from vertex to clypeo-labral suture, with two forks, one internal, curving anteriorly, the other directed laterally and continuing from vertex to posterolateral apex of clypeo-labral suture. Distribution (fig. 62).

Species description. — HOLOTYPE MALE. Size moderate for genus, form slender. Body surface dull, setose, especially on appendages. HEAD dorsoventrally elongate, genae only feebly laterally com-

	Measurements (in mm)				
	Length body	Length pronotum	Breadth pronotum	Length femur III	Length ovipositor
MALES (all last instars)					
Santa Rosa	12.5	2.6	2.2	8.3	
Santa Rosa (Wreck Cyn)	17.0	3.4	2.3	8.9	
San Miguel	14.7	2.8	2.2	8.8	
San Miguel	16.5	2.9	2.2	8.1	
FEMALES					
Santa Rosa *	20.0	3.2	2.8	9.8	1.5
San Miguel	16.5	2.9	2.3	9.9	2.1
San Miguel	15.6	3.2	2.7	9.6	1.5
San Miguel	13.0	2.8	2.3	10.0	1.9

* Holotype.

pressed, eye dorsoventrally elongate, surface slightly bulging, less than twice as long as broad (1.20 × 0.70), internal margin straight, external margin convex in dorsal one-third, in length less than twice that of first antennal segment (1.20 × 0.9); fastigium more than twice as broad as first antennal segment (1.5 × 0.9), surface smooth; first antennal segment little more than twice the length of second (0.9 × 0.4), ventro-internal margin obtusely produced; second segment shorter than third, the latter less than twice the length of former (0.40 × 0.70). Total length of antennae three times that of the body. Segments of maxillary palpi missing, see allotype. THORAX: Pronotum with distal margin extending to a point mesad between fore and middle coxa when viewed laterally, ventral margin of lateral lobe truncate, surface smooth; length of pronotum when viewed laterally less than combined length of meso- and metanota (3.1 × 1.8 × 1.8); margins of all thoracic nota with a narrow mantle; fore and middle coxae each with a distinct tooth, that of mesocoxa sharp, elongate; hind coxa without any trace of tooth. Fore and middle legs armed in the usual fashion for genus; hind tibia armed with ten teeth on internal margin, thirteen teeth on external margin, the first four or five in proximal position greatly reduced; prosternum armed with a pair of small broadly triangular projections, meso- and metathorax with hardly any development, projections indicated as feebly produced knobs. Stridulatory area of inner face of hind femur indicated as four diagonal, parallel rows of pegs, the rows much more closely spaced than in other species, dorsal transverse row poorly indicated. ABDOMEN with ventral portions of first two tergites with dense mat of stridulatory pegs, the area occupied on the second tergite fully twice that of the first; tenth tergite produced as in figs. 53, 54, internal margin distinctly bilobed, armed dorsolaterally with a very large spine directed anterior; cerci elongate, apex somewhat tapered, curved inward; paraprocts greatly produced, very elongate, in length more than three times apical width, armed subapically on latero-external margin with a minute, sharp spine, apex not appreciably bulbous, sparsely setose; genitalia large, protruding from abdomen, lateral lobes acutely pointed, with an accessory flange ventrad; subgenital plate well developed, shallow, much more than twice as broad at base than median length (3.2 × 1.1); median incision broad, distance between styles 1.6, style 0.3. COLORATION and SETATION. Head (fig. 61) with vertex with broken patches of fusco-testaceous, inverted Y-pattern distinctly indicated, arms of Y-staggered; genae with margins rimmed with fuscous; frons with triangulate faint fuscous region dorsad of clypeo-labral suture, a pair of longitudinal grey stripes running from lateral edges of fastigium to just dorsad of median of frons; clypeus unmarked; eye uniform black, small portion of dorso-internal region white; vertex with a fuscous to black stripe running from beyond dorsum of eye, through eye ventrad to clypeo-labral suture, region ventrad of eye expanded; stripe barely bifurcated, first fork directed mesad from base of stripe; second fork directed laterally,



FIGURES 53-61. — Diagnostic structures in *C. spinulus*. Fig. 53, lateral view and fig. 54, ventral view apex of abdomen of allotype; figs. 55, 56, same of paratype, Santa Cruz Island; fig. 57, dorsal view apex of abdomen and fig. 58, lateral view of abdomen of holotype; fig. 59, subgenital plate male; fig. 60, dorsal view pronotum, fig. 61, lateral view head male. Magnification: figs. 53, 55, 60, 61 12×; figs. 54, 56, 57, 58, 59 25×.

recurved distad, thence obsolete and continued ventrad along margin of gena to clypeo-labral suture. Antenna with flagellum uniform dark brown, first segment cream, internal obtuse projection fusco-testaceous; second segment with lateral portion cream, internal portion fuscous. Dorsum of insect with a thin but continuous stripe running from anterior margin of pronotum to abdominal apex. Surface of insect distinctly two-striped for entire length; lateral lobe of pronotum with extensive creamish area; lateral lobes of meso- and metanota white in median portion, ventral portion infuscate. All tibiae basically white with a faint grey overcast, anterior surface of fore tibia greyish, proximal area with a distinct grey annulus, middle tibia similarly marked; fore femur white, posterior surface with greyish overcast; middle femur white, anterior surface with distinct longitudinal stripe; hind femur with characteristic pattern, dorsal cross-hatching broken by a zig-zag longitudinal stripe, ventral border of cross-hatching with a continuous longitudinal stripe. Setation pronounced, but only on head and appendages, dorsal and lateral surfaces of insect lacking setation. Fore tibia with anterior ventral margin with increased setation to some extent, but not as great as in other species of the genus; cerci and spurs clothed with long setae, the latter mostly in proximal portions, if at all. ALLOTYPE FEMALE. Similar to male except as follows: size somewhat larger; basal portion of seventh abdominal sternite with expanded tubular projection plainly visible externally; subgenital plate twice as broad as long (2.5 × 1.2), apex without an acute digitiform process; ovipositor (figs. 57, 58) elongate (8.0) very feebly directed upward, smooth, distinctly narrowed in small region of distal one-third (0.8), widest point near base (1.5), apex acute, appreciably expanded ventrad. Coloration similar to that of male except two-striped appearance less distinct, dorsal surface of abdominal tergites with more brown coloration; eye stripe on head better indicated; ovipositor basically straw brown, apical one-third dark brown.

Variation. — The most obvious variation observed in adults of this species is that of coloration. The intensity of the color and extent of the internal fork of the eye stripe varies from nearly obsolete (male paratype) to heavy and nearly continuous to vertex (allotype). In all examples the internal furcation is present, but is sometimes faint. The two-striped appearance of the insect is sometimes lost (as illustrated by the allotype) due to the overall intense dark coloration. Morphologically the series shows no appreciable variation from that as described for the holotype and allotype.

Specimens examined. — CALIFORNIA: SANTA BARBARA COUNTY: Santa Cruz Island, 250′ elevation, Research Station, 14 June 1972 (D. C. Rentz, D. B. Weissman, 1 ♂, 3 ♀ ♀). VENTURA COUNTY: East Anacapa Island, 200′ elevation, near lighthouse, 8 July 1971, (D. C. Rentz, D. B. Weissman, 2 ♂, 2 ♀ ♀, all nymphs). Middle Anacapa Island, 20 July 1972, 20 to 100 ft. elevation, matured September, 1972 (D. B. Weissman, 2 ♀ ♀). West Anacapa, Frenchy's Cove, 23 June 1971 (D.

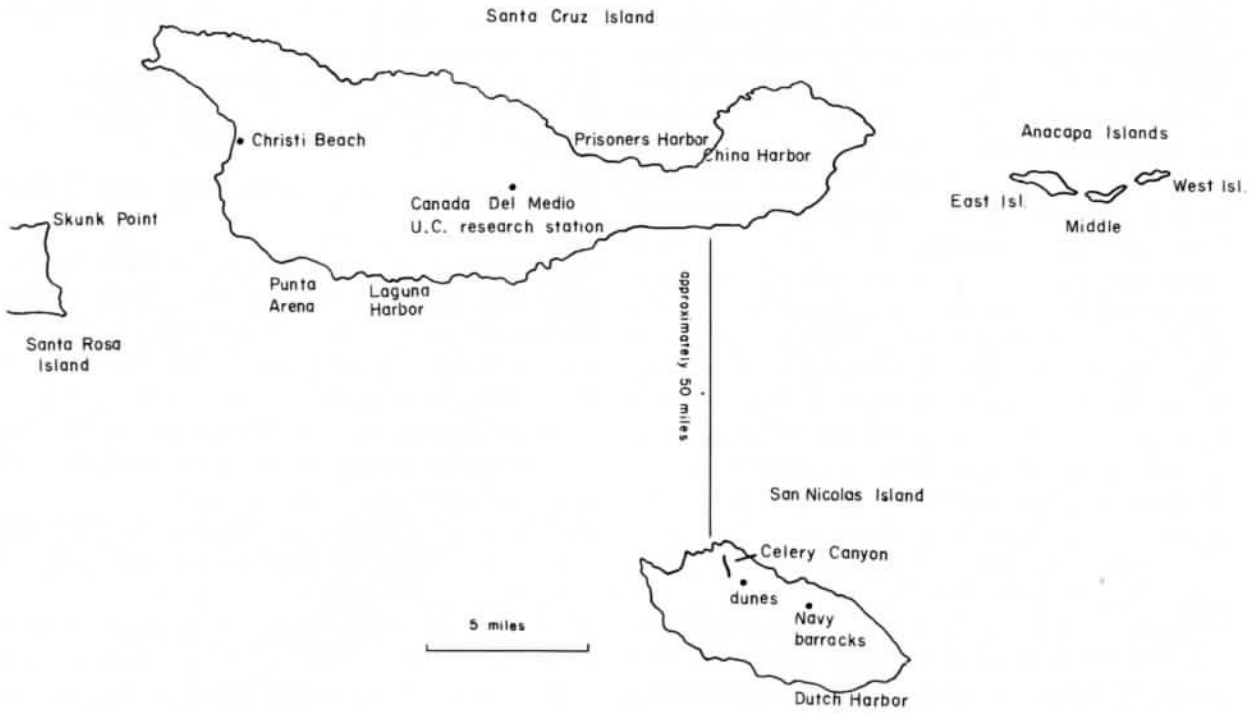


FIGURE 62. — Known distribution of *C. spinulus* on Santa Cruz, San Nicolas and the Anacapa Islands. Note discrepancy in scale between San Nicolas and Santa Cruz Islands.

C. Rentz, D. B. Weissman, 1 last instar ♀, prey of wasp *Palmodes insularis* Bohart and Menke, det. A. E. Menke). San Nicolas Island, dune area, NW corner of island, 0.6 mi. SE Celery Canyon, 13 June 1971 (D. C. Rentz, D. B. Weissman, 1 ♂; immatures, various instars, 6 ♂ ♂, 1 ♀); 15 July 1972, matured early September 1972 (D. B. Weissman, 1 ♂, 2 ♀ ♀, 1 immature, holotype, allotype).

Bionomics. — The type series was taken in an area (fig. 52) of rolling sand dunes. The sand here is loose, and the burrows, which are silk lined, are six to ten inches long. Entrance openings to such burrows were circular and not ∩-shaped as often seen in other species. Burrows not occupied by the crickets were found to contain pillbugs, wasps, or spiders, the latter of which were also in silk-lined burrows. The crickets always seemed to be found in association with *Ambrosia* roots: extensive digging around grasses and other plants failed to reveal any *Cnemotettix*. The sand of the habitat was relatively loose and moist within two inches of the surface. The silk-lined burrows retained their shape when the sand around them was disturbed. The populations structure at the time of the original collection, 13 June, was largely nymphal and only a single adult was found. At the type locality, the pristoceuthophiline camel cricket *Pristoceuthophilus* species was found in burrows, not silk-lined, in the same general area as *Cnemotettix spinulus*. However this species appeared to be highly localized and was never found with *Cnemotettix*.

As with other arenophilous *Cnemotettix* species, *C. spinulus* on San Nicolas Island apparently does not venture out on the dune surface every night. Other Pacific Coast dune crickets such as *Rhachocnemis validus* may be found shortly after dark on the surface of the dunes nearly every night. On the night of 15 July 1972 the sand dune area of San Nicolas was revisited after 9:30 P.M. (PDST) (civil twilight was at 8:40). No crickets were found on the dune surface, but digging revealed numbers of nymphs in their burrows seemingly no more active or alert than when they dug up during the daytime. The weather conditions at this time were as follows: relative humidity, 84%, temperature 64°F, wind

speed five knots. It was a new moon. A similar mainland habitat under the same weather conditions would have had considerable activity of other camel crickets.

Cnemotettix spinulus occupies vastly different habitats throughout its range. But, lack of adult males from the northern Channel Islands prevents us in stating with certainty that the species there is conspecific with that from the type locality, San Nicolas Island. The last instar and younger males present in our collection bear a minute spine on the paraproct, of much less development than in males of similar age of other species. The females agree well with those of topotypical *C. spinulus*. We, therefore, place the specimens from Santa Cruz and the Anacapas here as either representative of this species or a closely related one.

On Santa Cruz Island, *C. spinulus* is apparently quite rare in nature. This island is relatively well collected entomologically owing to the presence of the Research Station (fig. 63) operated by the University of California. Repeated collecting at different seasons over the past several years yielded specimens only in 1972. These were attracted to oatmeal spread along the dirt road beneath eucalyptus trees in the vicinity of the research station. The area is vegetated largely by live oak (*Quercus agrifolia*) and large planted gum eucalyptus on the low-lying plains. Considerable stands of chamise (*Adenostoma fasciculatum*) and toyon (*Heteromeles arbutifolia*) can be found on the hillsides and ridges. One of the females was found on the road in the Adenostoma-Toyon habitat; the remainder were found well within the heavily planted eucalyptus forest. A single female was observed ovipositing on the road. The soil in the area of collection is excessively hardpan clay; with sandy, loose soil only present in the adjacent streambed which is dry and exposed during much of the year. This habitat was carefully searched since it "appeared" more conducive to sand-burrowing crickets. However, none were ever found near this habitat. It seems probable that on Santa Cruz Island, *C. spinulus* lives in leaf litter. In the laboratory, the crickets readily burrow in loose sand, but they also utilize leaf litter in the construction of their burrows.

FIGURE 63. — Gum eucalyptus grove and portion of research station, habitat of *C. spinulus* on Santa Cruz Island.

Coastal dune areas on Santa Cruz Island have been searched intensively for *Cnemotettix* crickets at several times of the year, especially on the northwest side of the island at Christi Beach. This locality is only some seven miles east of Skunk Point, Santa Rosa Island where *C. caudulus* is abundant. At no time was there any indication of *Cnemotettix* crickets in the sand dunes. They are apparently restricted to chaparral habitats on Santa Cruz.

On East Anacapa, a fairly large series of specimens was obtained. Many are not indicated in the records because they subsequently died. All were found on the high point of the island near the base of the lighthouse, in burrows at the top of a precarious cliff. Whether the crickets constructed their own burrows is a matter of conjecture, since wasps, spiders, and other organisms were found commonly within the burrows. The substrate was fossilized sand dunes, extraordinarily hard. A hand shovel was necessary to break through the material. Most of the crickets were found well beneath the surface of the ground and often within proximity of buried rocks. Vegetation in the immediate area was reduced to a few scattered grasses. Some fifty feet distant coastal scrub vegetation was present.

On Middle Anacapa, *C. spinulus* was found in an area of *Coreopsis, Artemesia, Lotus, Eriogonum,* and *Dudleya* (fig. 64) on dry, loose clay, along a trail. The substrate appeared to be too hard for the crickets to dig in, but there were numerous cracks into which they could hide and some leaf litter under the plants. On the night of 20 July 1972, the following notes were taken: "moon in three-quarters phase, visible until 9:30 P.M. when it set. A couple of *Neduba* were calling prior to sunset but they stopped after dark. At 10:30 no stridulation was

	Measurements (in mm)				
	Length body	Length pronotum	Breadth pronotum	Length femur III	Length ovipositor
MALES					
San Nicolas *	16.4	3.3	2.3	9.7	
San Nicolas	17.3	3.6	2.5	10.5	
Last instar East Anacapa	17.8	2.9	2.3	10.1	
FEMALES					
San Nicolas *	16.5	3.7	2.6	9.9	8.0
San Nicolas	15.5	3.5	2.5	9.5	7.2
Santa Cruz	19.5	4.5	3.3	12.4	9.7
Santa Cruz	19.0	4.0	2.7	11.6	8.7
Santa Cruz	18.0	4.2	3.3	12.4	10.5
Last instars					
West Anacapa	19.5	3.8	2.6	11.2	7.3
Middle Anacapa	19.0	3.7	2.7	12.0	7.2
Middle Anacapa	×	3.7	2.6	10.1	7.2

* Holotype, allotype.

heard, very windy and cold. Went to bed, arose at 2:00 A.M. Many *Neduba* singing, no wind. Collected two female *Cnemotettix spinulus* on trail, one possibly ovipositing. Searched until 2:30 A.M. Arose at 4:00 A.M. Found four juvenile *C. spinulus* along trail. *Neduba* still calling."

On West Anacapa we found only a single specimen, a last instar female collected at 10:00 A.M. as it was being dragged by a sphecid wasp, *Palmodes insularis*. The specimen was found on the upper beach at Frenchy's Cove adjacent to a rockslide at the base of a cliff. The wasp was not flying with the much larger cricket, but was dragging it on the ground. Additional search failed to yield more specimens. Soil along the hillside adjacent to the beach was loose, with many large rocks and smaller fragments. It was not sandy, and much lighter in color than the fossilized sand of East Anacapa.

FIGURE 64. — Habitat of *C. spinulus* on Middle Anacapa Island. Predominant plants are *Coreopsis, Artemisia,* and *Eriogonum.*

Two Santa Cruz Island crickets laid eggs in the laboratory on or about 28 August 1972 and these eggs measured roughly 2.8 × 1.1 mm. They were placed on filter paper, in petri dishes, moistened with distilled water and kept at 25°C: they began to hatch on 16 October 1972. The first instar nymphs were able to spin silk at once and when placed in fine sand, immediately began to dig burrows and line them with silk. The first instars measured 4.7 mm in length.

CONCLUSIONS

Cnemotettix is a peculiar representative of the orthopteran fauna of western California both taxonomically and biologically. Its occurrence on the Channel Islands is of interest and the limited distribution of the species on the islands are of zoogeographic interest.

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